WEALTH TAXATION IN A LIFE-CYCLE MODEL WITH
ENTREPRENEURSHIP AND HOUSING

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Abstract

A standard heterogeneous agent, two-asset life-cycle model is developed, which includes entrepreneurship and a dual role for housing assets. Housing assets serve both as collateral for loans and as a good that generates a service flow. The life-cycle model allows me to replicate the pattern of wealth holdings that is estimated from a partially linear regression, based on data from the Survey of Consumer Finances. Results suggest that, regardless of occupation, young households hold relatively less financial wealth and most of their wealth is in the form of housing assets. The levels and trends of financial and housing asset holdings are quite different between wage earner households and business (entrepreneur) households. In the median wage earner household, the age profile of housing stock is hump-shaped, but it exhibits a flattening out pattern in the second half of lifetime. The holding of net financial assets has an S-shaped age profile. In comparison, regardless of whether the asset type is housing or net financial assets (which include business equity), the asset holding of the median business household grows steadily over the life cycle.

A calibrated version of the life-cycle model is developed and used to simulate counterfactual tax policies. These simulations are used to determine if a revenue-neutral introduction of wealth taxes brings about welfare gains (losses) in the U.S. economy. Quantitative inspection of the model performance suggests that a life-cycle model with collateral-based borrowing and entrepreneurship is more successful in capturing the age profile of wealth holdings as well as the fat-tailed distribution of wealth observed in the U.S. data. The quantitative analysis shows that a wealth tax policy reform decreases the aggregate capital stock. This causes a rise in the interest rate, but a decline of the wage rate. Young households are worse off because the decrease of labor income slows their accumulation of wealth, particularly in the form of housing assets. Old households also incur losses in social welfare because the first-order effect of a wealth tax reform is to increase their tax payments and reduce their consumption. With respect to aggregate output, these results suggest that a proportional (flat-rate) capital income tax policy is superior to a progressive wealth tax policy (which has been proposed by Piketty). Changes in the Gini index of the pre-tax income or post-tax wealth distributions indicate that a progressive wealth tax accomplishes a more equal distribution of income and wealth than the proportional capital income tax. I conclude that, from a political economy perspective where people vote according to their gains (losses) of social welfare, a progressive wealth tax is not likely to be favored by a majority of the population when the alternative is a proportional capital income tax.

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Chapter 1

Introduction

The distributions of income and wealth in most countries for which there is reliable data are skewed to the right, with thick upper tails showing large and slowly declining top income and wealth shares. According to the estimates in Saez and Zucman (2016) for the United States, the share of total wealth held by the top 1% was around 25% in 1980 and has increased to exceed 40% today; for the top 0.1% it even doubled from less than 10% to over 20% during the same period of time. These statistics essentially reflect economic inequality, which is in tandem with wealth concentration, and have drawn strong attention in academic, policy and media circles. Recent bestselling books reflect attempts to assess the causes and consequences behind inequality, and contrive a remedy for it. Stiglitz (2015) argues that much of the inequality has been the result of rent-seeking by, for example, winning preferential tax treatment or government-protected market share, because, to a large extent, rent seeking redistributes money from those at the bottom to those at the top with economic power to insulate themselves from competitive forces, and that economic inequality leads to democratic instability. Piketty (2014) and Atkinson (2015) suggest progressive tax schemes with higher taxes on the wealthiest to supplement the re-distributional effects of the income tax.

This work investigates the macro effects of wealth taxation at the quantitative level by conducting counterfactual policy experiments with a calibrated model built under a standard heterogeneous agents life-cycle framework, pioneered by Huggett (1996). A contribution is to accounts for two features unconventionally appearing together in a discrete-time life-cycle economy—the role of entrepreneurship and the function of home equity-based borrowing—for describing life-cycle savings behavior of business households as well as distributional and welfare impacts of wealth taxes in the economy. The main result of this work is that capital income taxes are not necessarily outperformed with respect to welfare effect by a progressive wealth tax.

Households reporting self employment as their major source of income or own a business with an active role in management constitute a unique group in the population and contribute to the economy in a disproportionate and significant way. Despite making up only a small fraction of the population (roughly 11% of the total), business households hold a substantial share of household wealth (40%) in the United States.[1] Empirical evidence shows that even after controlling for income, the net worth of business owners is much higher than for other households, suggesting saving behavior differential between entrepreneurs and workers.[2] The concentration of household wealth implies that entrepreneurial saving

[1]Díaz-Giménez, Glover, and Ríos-Rull (2011) document that the self-employed make up 10.5 percent of the 2007 Survey of Consumer Finances (SCF) sample. Gentry and Hubbard (2004) report that entrepreneurs own 40.8% of total assets among active business owners. Quadrini (2000) reports the share of entrepreneurs in the U.S. at 12% using the average of family data from the Panel Study of Income Dynamics (PSID) for the period of 1970-1992 and from the SCF data for 1989-1992; they own 40% of the total wealth.

[2]Dynan, Skinner, and Zeldes (2004) find that higher-lifetime income households save a larger fraction of their income. Gentry and Hubbard (2004) report wealth-income ratios being higher for entrepreneurial households and saving-income ratios being higher for entrants and continuing entrepreneurs, even after controlling for age and other demographic variables. Quadrini (1999) finds the ratio of wealth to income is about twice as large for business families as worker families.

decisions may have important implications for models of wealth distribution or aggregate household consumption and saving.

Previous work has found nascent entrepreneurs save for the purpose of relaxing the credit constraints on business entry and for anticipated business investment needs.[3] According to the prediction of intertemporal models of consumption and saving behavior under risk and borrowing constraints, individuals hold assets to insure themselves from unexpected income realizations—a behavior which is referred to as consumption smoothing/precautionary saving.[4] Given that entrepreneurs face extra income uncertainty arising from business risk taking—relative to wage earners, who are primarily exposed to labor income risk—entrepreneurs may have exclusive needs to buffer themselves from idiosyncratic business income draws and hence accumulate more wealth than others with incentives beyond usual precautionary motives.[5]

Some papers have documented that the wealth of entrepreneurs tends to be narrowly sourced, which is suggestive of limits in their accessibility to external funding due to financial friction.[6] In the theoretical literature, the credit constraints (or more generally the high cost of external finance), the minimum capital requirement for business entry, uninsurable business risk taking rewarded by higher expected investment returns are features

[3] Evans and Jovanovic (1989) and Cagetti and De Nardi (2006) shows that credit constraints at the household level matter for the creation of new business, although some authors have argued that the relationship of wealth with business entry is present only at the very top of wealth distribution; see Hurst and Lusardi (2004). With more advanced technique of econometric analysis, recent literature justifies the existence of the relationship; see Fairlie and Krashinsky (2012) and Schmalz, Sraer, and Thesmar (2017).

[4] See Carroll (1997), Deaton (1991), and Modigliani (1986).

[5] Hurst *et al.* (2010) use subgroup data from PSID to show, when controlling for business ownership, the size of precautionary savings with respect to labor income risk is modest and accounts for less than 10% of total household wealth. The result suggests that a huge share of entrepreneurial wealth could not be explained by precautionary motives.

[6] See Gentry and Hubbard (2004) and Quadrini (1999) for empirical evidence based on the U.S. data.

characterizing the environment of entrepreneurs. In the literature of entrepreneurial models, these elements constitute the mechanism to drive households to save more and shape the concentration of the wealth distribution in a model economy.

1.1 Problem statement

To compare different policy consequences, I need a framework that accounts for drivers of the wealth distribution over households where account is taken of their heterogeneity in age, labor efficiency, entrepreneurial ability, asset holdings and luck in running a business. Models based on earnings shock and precautionary savings alone tend not to replicate the observed features of wealth distribution with the thick upper tail, featuring a large and slow decreasing top wealth shares.[7]

Recent theoretical literature has shown that, under substantially weak assumptions on consumption function and random processes of earnings and returns, stochastic asset returns is one plausible candidate to help reproduce the fat upper tail of the wealth distribution in a calibrated model.[8] Some authors have found that compensation to entrepreneurs, i.e., risky entrepreneurial rent, is a feasible proxy for stochastic returns on investment, which is deemed as one potential extension for generating a fat-tailed wealth distribution, as observed in the data.[9] In the heterogeneous agents literature, models which exploit the role of entrepreneurial function to reproduce the wealth concentration are mostly built under

[7]De Nardi, Fella, and Pardo (2016) show that earnings data fro non-entrepreneurs do not feature sufficient downward risk to generate a thick upper-tail in the wealth distribution as a result of precautionary saving.

[8]Benhabib and Bisin (2016) survey theoretical literature and identify three basic mechanisms that can contribute to generate wealth distributions that have thick upper thick tails: skewed earnings, stochastic returns on wealth, and explosive wealth accumulation. Quadrini and Ríos-Rull (1997) note that business ownership and increasing asset returns and capital gains are promising features underlying the generation of wealth concentration observed in the U.S. data. Hubmer, Krusell, and Smith (2016) suggest introducing more heterogeneity in preferences, in the wage/earnings process, or in occupation in order to match the data better.

[9]Modeling stochastic wealth returns in the form of business returns is one of extensions for replicating the highly skewed wealth distribution; see Benhabib and Bisin (2016) and Cagetti and De Nardi (2008).

an infinitely-lived agents framework. However, little of existing research has explicitly used life-cycle patterns and heterogeneity in household asset holdings to enrich our understanding about the primary determinants of these household choices over the lifetime. The challenge is whether the same interpretation for the cross-sectional variation of household saving behaviors can be extended to the life-cycle dimension (where age is the additional state variable) remains unaddressed.

It is known that a major fraction of total wealth for most households is in the form of housing—which is a relatively illiquid and indivisible type of investment, with unique risk and tax characteristics, as compared to financial wealth such as money, bonds, and savings accounts. The empirical literature has found that household wealth holdings are very heterogeneous by age, income and occupation.[10] In a life-cycle setting, the literature has shown that the fraction of risky assets in the asset portfolio should decrease with age as people move closer to retirement.[11] When analyzing the effects of taxation, macroeconomics typically assumes a single riskless asset, or at most two, for example, when entrepreneurial investment (business capital) is included.[12] This allows a considerable simplification, at the potential cost of ignoring the policy implications of household heterogeneity across asset categories and age groups with respect to asset holdings.

Entrepreneurship has been introduced in the study of the distributional effects of a variety of taxation.[13] In this branch of the literature, most of the entrepreneurial/occupational

[10]See Banks, Blundell, and Smith (2003); Heaton and Lucas (2000); Yang (2009).

[11]See Benzoni, Collin-Dufresne, and Goldstein (2007); Bloom, Canning, and Graham (2003); Campbell and Viceira (2002); Jappelli and Modigliani (1998)

[12]For example, one of the early optimal capital taxation papers by Chamley (1986) considers only a riskless security. In the same line of literature, the overlapping generations model proposed by Conesa, Kitao, and Krueger (2009) uses a riskless asset as well but reaches a conclusion different from that of Chamley (1986). A growing literature of wealth distribution and taxation uses a occupational choice framework that accounts for business capital, whose rate of returns is by construction not riskless; See Cagetti and De Nardi (2006); Kitao (2008); Ocampo *et al.* (2017).

[13]In the entrepreneurial literature, Cagetti and De Nardi (2009) focuses on estate taxation; Chen, Qi, and Schlagenhauf (2017) on corporate income tax; Kitao (2008) on taxes imposed on different income sources; Meh (2005) on a progressive income tax system; Ocampo *et al.* (2017) on wealth taxation.

choices models abstract from the function of home equity as collateral in debt obligations. In reality, collateral borrowing is an important means for households to overcome credit constraints. Indeed, recent papers, using a probit regression model with suitable instrumental variables to deal with endogeneity, have found that the value of home equity is positively related to entrepreneurial entry.[14] To the extent that housing is a collateralizable asset and a partial substitute for a liquid asset, it is highly probable that household responsiveness to policy differs significantly across housing and nonhousing assets. In this case, removing the role of housing assets from the model environment would undermine the reliability of model prediction in the study of policy and welfare.

With the absence of housing assets, a policy analysis of wealth taxation of this kind fails to recognize the negative impact on welfare because housing asset holdings would otherwise not be taxable. Consider an extreme one-period case of a tax reform in an island economy. On the island live two brothers, Henry and Frank. The brothers are endowed with the same amount of capital worth \$2000. Henry holds 100% of his wealth in the form of housing asset. On the contrary, Frank saves 100% of his wealth in savings account. Suppose that a flat-rate capital income tax is implemented at the rate of 20% and the interest rate of a saving account is 10%. The tax revenue collected by the government under the flat-rate capital income tax scheme totals \$40 (2000*10%*20%), paid entirely by Frank.

Suppose that a revenue-neutral proportional wealth tax is introduced in place of the flat-rate capital income tax. The required rate of the wealth tax is 0.95% (40/(2000+2000(1+10%))). Frank's post-reform tax payment drops by 48% from \$40 to \$21 (≈2000*(1+10%)*0.95%). In comparison, Henry's post-reform tax payment surges from nil to \$19 (≈2000*0.95%), or his tax burden measured by the ratio of taxes to wealth

[14]Some empirical papers, based on different sources of data, show that housing asset holding is a determinant for the business creation; see Corradin and Popov (2015), Fairlie and Krashinsky (2012), Jensen, Leth-Petersen, and Nanda (2014), and Schmalz, Sraer, and Thesmar (2017).

increases from zero to 0.0095 (≈19/2000). In a more realistic scenario where there exists wealth inequality in this island economy and Henry represents the low-wealth household with the capital endowment worth \$100. In this case, Henry's post-reform tax burden almost doubles (0.0174≈40/(100+2000(1+10%))). To sum up, the impact of wealth taxation at the household level is determined by the composition of the household asset portfolio and thus varies across households. For those low-wealth households, it is highly probable that they would hold less housing stock in response to the implementation of the flat-rate tax reform in order to shelter themselves from paying more tax payment because of the first-order effect of the flat-rate wealth taxation.

Motivated by the problems mentioned above, I examine three central questions in this work: (1) Are the life-cycle saving behaviors of entrepreneurial households and wage earner households different? (2) Can life-cycle patterns of wealth holdings in business households be produced by a life-cycle occupational choice (entrepreneurial) model? (3) Is wealth taxation (i.e., taxing the stock of household capital) a preferred tax policy when compared to capital income taxation (i.e., taxing the income inflow from capital)?

1.2 Research objectives

I answer these questions with a two pronged approach: a semi-parametric regression model and a general equilibrium model where household occupations are determined endogenously and home equity can be used as security for loans. The first question is positive in nature. My first objective is to characterize the life-cycle patterns of the median business household's wealth holdings with a partially linear regression model. It is a hybrid of a linear regression model with a kernel smoothing model (the former is parametric, while the latter is not). The raw data for the analysis comes from the SCF during the period 1986-2013. One technical challenge is that the demographic attribute, age, is a default state variable in a life-cycle analysis. However, the SCF is a cross-sectional household survey data, which is by no mean suitable for panel analysis because the SCF survey respondents are, by construction, not sampled repeatedly over time.

Following Deaton (1995), I bypass this problem by compiling the raw data into a pseudo panel data set such that only the summary statistics of the median households in groups of age are computed. With the resulting data set, a nonlinear regression analysis is conducted that regresses the dependent variables of interest on dummies for survey years, ages and cohorts. The dependent variables include the levels of the median household's housing asset holding and financial wealth holding. Based on the estimated partially linear regression model, I capture the levels and trends of the housing and nonhousing asset holdings over the life cycle of the median business household. Another function of the estimated life-cycle patterns is to be used in the subsequent analysis for graphical inspection to check whether or not the calibrated version of the proposed life-cycle model reasonably replicates the estimated age profile of household wealth holdings.

To answer the second central question, I propose a model on the basis of Huggett's (1996) life-cycle model.[15] I extend his model by adding two additional features: the role of entrepreneurs and the dual function of housing as a collateralizable asset and a good providing service flow. The formulation of entrepreneurship is akin to the modeling strategy of Quadrini (2000), where individuals make occupational choices subject to idiosyncratic uncertainty in entrepreneurial ability and labor productivity. The mechanism of borrowing

[15]The life-cycle model proposed in this work inherits a set of variations of the features from the heterogeneous agents life-cycle framework proposed by Huggett (1996). They include (1) income, earnings, and longevity uncertainty, (2) institutional features such as social security and taxation, and (4) market features such as borrowing constraints and the absence of insurance markets.

against the housing asset is embedded into the household borrowing constraint (see Cocco (2005) and Silos (2007) for similar model setup).

There are two types of households in the model. The number of each type is determined endogenously. At any point of time, households are heterogeneous in age, the size of financial wealth and housing asset, and occupation. Worker households (similar to consumers in the standard representative agent economy with production) exchange labor efficiency endowment for wages, while business households are responsible for servicing their business loans and making decisions on hiring factors of production. The entrepreneurial households engage in a risky project with a production technology exhibiting decreasing returns to scale and earn idiosyncratic returns on business investment under uncertainty. The stochastic mechanism behind this setup is defined by an exogenous Markov process.

In addition, there also exists a corporate (non-entrepreneurial) sector that offers non-stochastic returns and features anonymous business decision making. Households with entrepreneurial talent save for and invest in business projects that entail a minimum capital requirement. Constrained households may choose costly external loans with own housing asset as collateral. Households without entrepreneurial talent allocate their savings to risk-free assets for smoothing consumption and for future business opportunity. Thus, this model describes an economy wherein a fraction of the households choose to become entrepreneurs while the others live on wages and returns from savings in the form of riskless financial assets as their main income source until they have sufficient capital and entrepreneurial talent to transit from wage-and-salary to self-employment.

To answer the second central question, my research objective is to determine if a calibrated heterogeneous agents model of home equity-based borrowing by liquidity-constrained households with extra heterogeneity in occupation can account for the differentials in the empirical life-cycle patterns of asset holdings between business and nonbusiness households. In other words, the same theory in characterizing the role of entrepreneurship in the infinitely-lived framework, can be shown to be sufficient to produce the heterogeneity in age profiles of wealth holdings that looks similar to their empirical counterparts in the data.

The third question is normative in nature. To complement the discussion revolving around Piketty's (2014) wealth tax policy, I evaluate the welfare impact of the basic version of his proposal by examining how a wealth tax impacts the economy as opposed to a tax on capital income. I exploit the calibrated version of the baseline model as the vehicle for policy experiments. My third research objective is to determine if a change from a single proportional capital income tax to a mixture of capital income tax and a Piketty-type (2014) progressive wealth tax scheme brings about any significant welfare losses or gains. I measure the transfer of taxation burden, and characterize how it is distributed across the population using a general equilibrium model that can explicitly study firm dynamics (entrepreneurial entry and investment), aggregate variables, factor prices, and asset portfolio choices across occupational and age groups of household.

To accomplish the research objectives, I perform several policy experiments to evaluate the effects of introducing capital taxes under three scenarios. In the calibrated model of the U.S. economy, the default tax scheme (denoted by $\mathcal{T}^0$) is a nonlinear function of household earnings as formulated in Gouveia and Strauss (1994).[16] Taxable household earnings in this economy can be divided into three categories: household incomes (wages, interests earned from savings, and business profits), government transfer (social security benefits), and intergenerational transfers (accidental bequests). In the first policy experiment $\mathcal{P}^1$, I conduct a tax reform from the initial tax scheme $\mathcal{T}^1$ to the alternative tax scheme $\mathcal{T}^2$. The

[16] Based on individual tax return data collected by the Internal Revenue Service, Gouveia and Strauss (1994) estimate a parameterized nonlinear function of individual total taxable income to approximate the progressivity of the U.S. federal income tax system.

initial tax scheme $\mathcal{T}^1$ is defined as a hybrid of the default nonlinear tax scheme with a proportional tax rate on capital income from savings set at 15%.[17] Since the capital income from savings is taxed individually, to avoid double taxing capital income from the same source, the tax base of the nonlinear taxation part in $\mathcal{T}^1$ only considers wage and business profits for the household incomes category—i.e., the nonlinear tax is not levied on interest earned from savings in $\mathcal{T}^1$.

(1) The first policy experiment (the proportional wealth tax): $\mathcal{P}^1$

$$
\begin{array}{llcl}
 & & \xmapsto{\text{Tax reform } \mathcal{P}^1} & \\
\text{Tax policy} & \mathcal{T}^1 & & \mathcal{T}^2 \\
\text{Economy} & \mathcal{E}^1 & & \mathcal{E}^2
\end{array}
$$

(2) The second policy experiment (the progressive wealth tax): $\mathcal{P}^2$

$$
\begin{array}{llcl}
 & & \xmapsto{\text{Tax reform } \mathcal{P}^2} & \\
\text{Tax policy} & \mathcal{T}^1 & & \mathcal{T}^3 \\
\text{Economy} & \mathcal{E}^1 & & \mathcal{E}^3
\end{array}
$$

Figure 1.1: Illustration of tax policy reforms.

In Figure 1.1, I illustrate by symbols the intended tax reforms, corresponding tax schemes and economies in policy experiments $\mathcal{P}^1$ and $\mathcal{P}^2$, respectively. The initial tax scheme in both of the policy experiments is $\mathcal{T}^1$. The alternative tax scheme to which a tax policy is changed is $\mathcal{T}^2$ in policy experiment $\mathcal{P}^1$ and $\mathcal{T}^3$ in policy experiment $\mathcal{P}^2$.

The alternative tax scheme $\mathcal{T}^2$ of policy experiment $\mathcal{P}^1$ repeals the capital income tax considered in the initial economy $\mathcal{E}^1$, counting accrued interest from savings toward household taxable earnings, and further introducing a flat rate of tax on household wealth. Wealth

[17] In the literature, the rates of capital income taxes commonly range from 10% to 40% in policy experiments. I choose 15% for convenience. A full inspection over a wider interval is left for future research.

is defined as net worth, which equals to the total of financial assets, housing asset, and business equity net of the value of debts. The flat wealth tax rate is pinned down endogenously by balancing the government budget in the stationary equilibrium.

In the second experiment $\mathcal{P}^2$, the tax policy is changed from the initial tax scheme $\mathcal{T}^1$ to the alternative tax scheme $\mathcal{T}^3$, which is a mixture of a flat-rate capital income tax with a progressive wealth tax that targets high-wealth households. Exemption levels are set for less wealthy households.

It is worth noting that each tax reform is revenue neutral in the sense that government revenues are assumed to remain the same in each tax policy experiment as in the stationary equilibrium of the baseline economy $\mathcal{E}^1$ (that implements the tax scheme $\mathcal{T}^1$).[18] Some authors in the literature choose to set the government spending to a fixed *fraction* of total output across different policies, but it is not the case in this study. Besides, to make all the policy experiments comparable with one another, the stationary-equilibrium features of the economy $\mathcal{E}^1$ is used as the benchmark to evaluate the distributional effects and the welfare costs and benefits under the other tax scenarios.

1.3 Organization

The rest of this study is organized as follows. Chapter 2 reviews the literature that is related to this study. In Chapter 3, I describe some stylized facts about the U.S. wealth distribution and the age profiles of housing and financial asset holdings for the U.S. worker and business households. Chapter 4 presents the quantitative framework for capturing the empirical life-cycle patterns of household asset holdings and fat-upper-tailed wealth distribution in the

[18]The government spending in the stationary equilibrium of the baseline economy $\mathcal{E}^1$ is assumed to be a fraction of total output plus interest expense on the debt outstanding. The debt outstanding is a fraction of total capital. Both of the fractions are exogenously given and same as in the literature.

U.S. Further, in Chapter 5, counterfactual tax policy experiments to quantitatively evaluate two variations of wealth-based taxation are discussed. Chapter 6 concludes the study.

Chapter 2

Literature Review

To the best of my knowledge, this study is the first work that evaluates wealth taxation by using a quantitative, general equilibrium, life-cycle model that takes into account occupational heterogeneity with an entrepreneurial sector and the dual role of housing acting as a good generating service flow and as collateral for loans. The model matches a number of important macro aggregates such as the fraction and total assets of business households, and most important of all, produces the life-cycle pattern of the median business household's wealth holdings that graphically fits their empirical counterparts.

This study is associated with existing work along different lines of the literature. The first one is the applied literature concerned with the dynamic impact of capital taxation when idiosyncratic shocks exist, financial markets are incomplete, tax instruments are restricted, and/or individuals are finitely lived. A number of studies found that it may be desirable to tax capital income and that the rate can be positive and large (see Aiyagari (1995), İmrohoroğlu (1998), Erosa and Gervais (2002), Conesa, Kitao, and Krueger (2009), Kitao (2008), and Ocampo *et al.* (2017)). The most related works are Kitao (2008) and Ocampo *et al.* (2017). The main difference between my analysis of theirs is the presence of housing asset in a life cycle framework with entrepreneurial talent and stochastic idiosyncratic returns on business investment. I show that incorporating housing asset into the analysis of wealth taxation alters some key conclusions (e.g., all else being equal, it become desirable to consider progressive wealth taxation, when housing asset is subsumed under total assets of households). Kitao (2008) studies important channels through which fiscal policies affect aggregate variables. With an infinitely-lived agents model, her policy experiments include the description of transition path between steady states, a feature which is abstracted from in my model due to extra computational workload incurred under a life cycle framework. Ocampo *et al.* (2017) investigate the equality and efficiency trade-offs of a flat wealth tax scheme. They find that a revenue-neutral tax reform replacing a capital income tax with a wealth tax increases welfare. The main feature that differentiates their model from mine is the setup of occupational decision-making. Ocampo *et al.* (2017) calibrate a stochastic process that assigns random shocks to business productivity at the firm/household level. Households who receive a positive business shock become entrepreneurs; otherwise, they are workers. Conversely, occupational status is determined not directly by luck in my model. Households make occupational choices by weighing the expected benefits of being a worker and being an entrepreneur after observing the realization of the stochastic endowments of labor efficiency and entrepreneurial ability. Further, my model allows business households to exit entrepreneurship upon receiving a bad business income draws. By doing so, my model induces more household heterogeneity, a feature which is supposed to make optimal household savings path more diverse over the life cycle.

Besides the literature in dynamic fiscal policies, this study is related to a large literature that studies the quantitative implications of models of occupational choice and borrowing constraints on wealth distribution and social mobility. The most related work are discrete-time entrepreneurial models studied by Cagetti and De Nardi (2006) and Quadrini (2000). These authors have shown that models accounting for entrepreneurship and borrowing constraints are important for explaining the wealth concentration in the upper tail of the empirical wealth distribution. Buera and Kaboski (2014), Cagetti and De Nardi (2009), Kitao (2008), and Meh (2005) quantify the effect of various tax and transfer policies in models embedded with entrepreneurs and credit constraints. Buera (2009) theoretically characterizes savings behavior by a continuous time analogy with this class of models; Vereshchagina and Hopenhayn (2009) study the discrete time version. My work contributes to this literature by providing the justification of the introduction of entrepreneurial function into life-cycle models for the purpose of replicating the fat tail properties of wealth distributions as well as the life cycle patterns of entrepreneurial wealth holdings.

The third literature this study is related to is the one that documents empirical life-cycle consumption expenditure and savings profiles. The methodology employed in this branch of literature is synthetic cohort techniques and partially linear regression analysis based on household-level survey data; see Carroll (1997), Deaton (1997), Deaton and Paxson (1994), De Nardi, French, and Jones (2009), Wunder *et al.* (2011), Wolff (2016). Among many others, Gourinchas and Parker (2002) use the Consumer Expenditure Survey (CEX) to construct age-profiles of consumption and income of typical households across education and occupation groups. They find that consumption and income are both significantly hump-shaped and consumption tracks income only early in life. Fernández-Villaverde and Krueger (2007) use data from the 1980-2001 CEX to estimate age-expenditure profiles for nondurable goods and consumer durables, and find significant humps over the life cycle for expenditures of both the goods. Based on the SCF and CEX, Yang (2009) investigates patterns of consumption for housing and non-housing goods over the life cycle. She finds similar hump-shaped consumption expenditure on non-housing goods to Fernández-Villaverde and Krueger (2007), displaying a trend that starts low early in life, rises considerably into middle age, and falls at a later stage of life. In contrast, she finds that household holdings of housing stock stop increasing around middle age and exhibit a flattened out pattern throughout the second half of life cycle. My work contributes to this line of literature by looking deeper into the subgroups of the populations (i.e., workers and entrepreneurs), and estimating the age profiles of housing and nonhousing assets across these two occupational groups. In contrast to the conventional notion about the hump-shaped life cycle patterns of household consumption and savings, I find that the age profiles of asset holdings, either housing asset or financial wealth (including business equity), increase monotonically throughout the lifetime of the median business households.

Lastly, my model is part of an expanding literature that analyzes the aggregate behavior of economies with heterogeneous agents and incomplete markets. Following the tradition of one-sector models with infinitely lived agents, however, these studies have mostly abstracted from housing altogether by treating housing as part of total capital stock, and limit their focus to interpret the cross-sectional features of data when age heterogeneity is not desirable. Some exceptions are discussed below.[1]

Silos (2007) examines the relationship between macroeconomic shock and household portfolio choices by adopting a standard overlapping generations (OLG) economy with two assets, where uncertain productivities at the aggregate and individual levels are both considered. His focus is on the impact of aggregate shocks on the wealth distribution and portfolio composition. Unlike Silos (2007), I concentrate on how idiosyncratic business

[1] See Chambers, Garriga, and Schlagenhauf (2009), Chen (2010), Cooper (2013), Davis and Van Nieuwerburgh (2015) for more applications.

shock and entrepreneurial ability are translated into the formation of wealth concentration through household asset portfolio decisions, particularly those of business households. Iacoviello and Pavan (2013) and Favilukis, Ludvigson, and Van Nieuwerburgh (2016) use an OLG framework with housing that considers the interaction between borrowing constraints and aggregate economic activity to address a set of different issues. One major difference in model setting between theirs and mine is the mechanism for generating wealth concentration. Iacoviello and Pavan (2013) exploit a heterogeneous-agent setting with preference heterogeneity. Favilukis, Ludvigson, and Van Nieuwerburgh (2016) induce the skewed wealth distribution by adopting a dichotomous classification of households according to bequest motives. On the contrary, my model assumes an identical household utility function and a unique discount factor across households. The dichotomy in my model is not determined by bequest preferences exogenously given, but by the fraction of business households pinned down in the stationary equilibrium endogenously. In this study, the heterogeneity in the rate of returns on business investment is the driver for reproducing the highly skewed wealth distribution, rather than the composite effect of the heterogeneity in preference or labor efficiency.

Chapter 3

Life-Cycle Profile of Asset Holdings

This section aims to draw a contrast in saving behaviors between business and non-business households. Some of the results are used as the benchmark for the graphical evaluation of the proposed model in capturing the features of U.S. household wealth holdings. Between the two occupational subgroups of households, of special interest is to evaluate the life-cycle pattern of housing and financial asset holdings on the basis of the Survey of Consumer Finances (SCF), a triennial interview survey of U.S. families undertaken by the Board of Governors of the Federal Reserve System. The survey collects information on families' total income but focuses primarily on detailed information about their balance sheets. The survey is regarded as the most authoritative source in the United States regarding micro-level data on household assets and liabilities.[1]

[1]The SCF survey adopts two techniques for random sampling: a standard, geography-based random sample of U.S. households and a complementary sample selected from a list of statistical records derived from tax returns to disproportionately include high-wealth families, which hold a relatively large share of rarely held assets, which include tax-exempt bonds and non-corporate businesses. Because of such a sampling design, the SCF data is statistically representative of the U.S. household population.

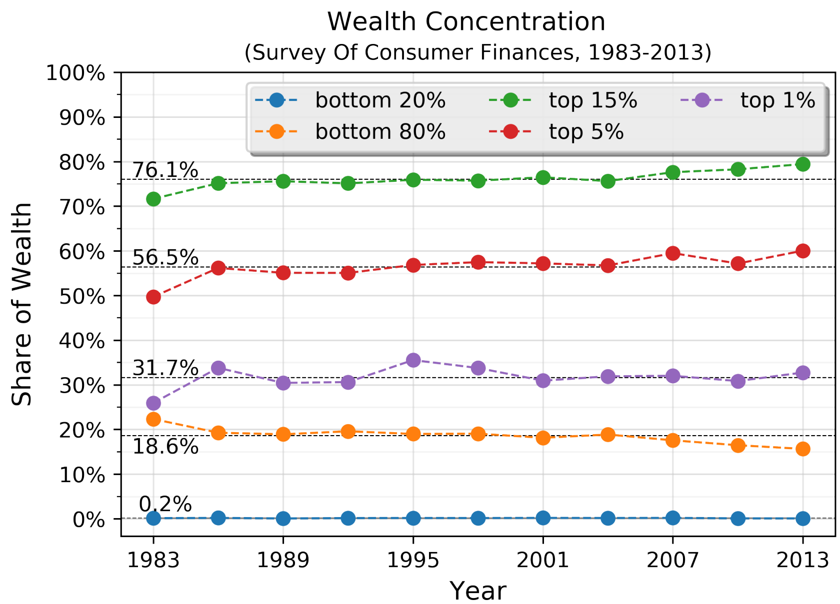

Figure 3.1: The uneven distribution of wealth in the U.S.

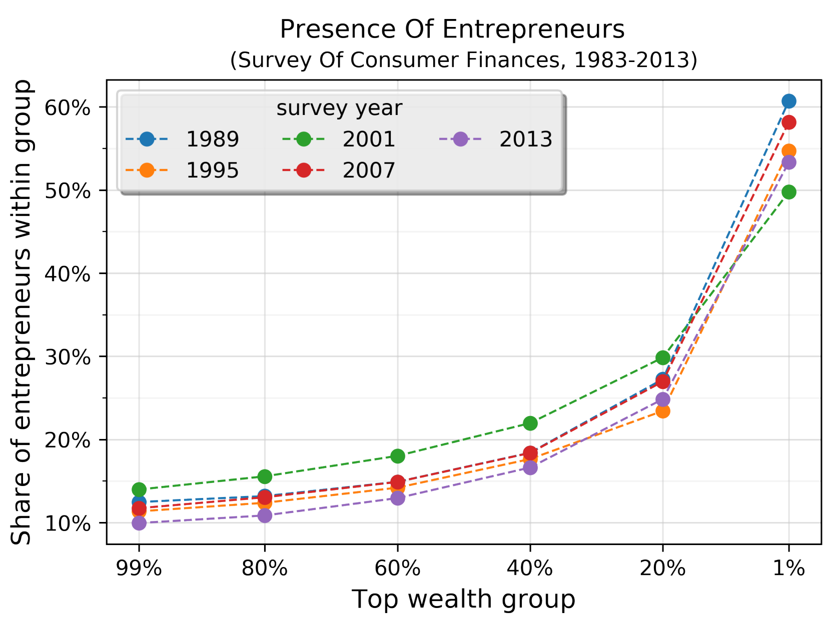

Figure 3.2: The dominant presence of business households in the top percentiles of the U.S. wealth distribution.

3.1 Cross-sectional features of household wealth holdings

Before I use statistical analysis for extracting the information about the life-cycle pattern of household asset holdings from the SCF data, some summary statistics of the U.S. wealth distribution and household asset composition are outlined as follows. In Figure 3.1, I show that the share of wealth held by the top 15%, 5% and 1% in the U.S. wealth distribution has been increasing over the past thirty years, while the proportion of wealth held by the bottom 80% keeps shrinking. The vertical axis refers to the fraction of total wealth; the horizontal axis represents the survey years. Each data point refers to the percentage of total wealth held by a wealth group in a given survey year. Data of the same wealth group is marked by the same color and connected by a dashed line. The horizontal dashed lines represent the average of percentage wealth holdings for a wealth percentile across survey years. On average, for example, the top 1% holds more than 30% of the total wealth during the period 1983-2013.

To take a closer look at the constituents of the top percentiles in the wealth distribution, I show in Figure 3.2 the percentage appearance of business households within a top percentile. The horizontal axis refers to the top percentiles. The presence of business households rises dramatically from an average of only 15% in the top 99th percentile households of the wealth distribution to more than 60% in the top first percentile. Although answering why the wealth concentration and the fraction of entrepreneurs in the U.S. data have been trending upward over the past thirty years is beyond the scope of this study, Figures 3.1 and 3.2 report that business households account for a small fraction of the population but hold a disproportional share of total wealth in the economy. The empirical findings imply that business households form the majority of the top percentiles.

Some argue that business households are richer simply because of their receiving higher incomes. Figure 3.3 casts doubt on this argument by showing that the net worth of business

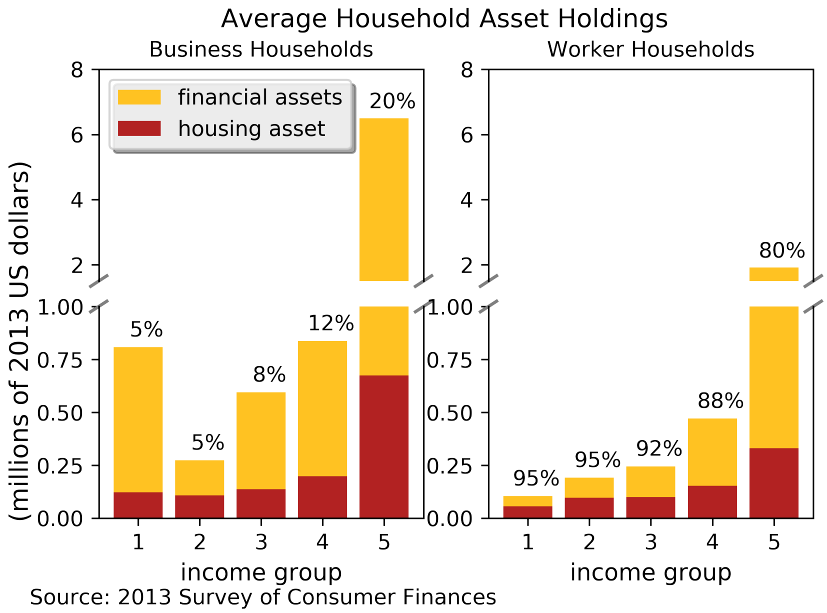

Figure 3.3: The composition of household asset portfolio across income quintiles.

households systematically dwarf that of worker households within the same income group. In Figure 3.3, I report the average wealth holdings of business and nonbusiness households and their percentage presence within the income quintiles. To emphasize the heterogeneity at the household subgroup level, I plot the bar chart for business households in the left panel of Figure 3.3, and the one for nonbusiness households in the right panel. Note that the horizontal axis of the two panels represents the same income quintiles generated from the income distribution over all the U.S. households, rather than a particular occupational subgroup of households. The vertical axis shows the amount of household total wealth. On top of each total wealth bar is the percentage presence of a particular occupational subgroup in the associated income quintile. To describe the variation in the composition of asset portfolio across occupational and income groups, I color the fraction of total wealth in the form of housing asset in red, and that of net financial asset holdings in yellow.

For example, when we look at the left-most income quintile on the left panel, it shows that business households take up only five percent of the first income quintile, and that the amount of their net financial asset holdings significantly exceeds the amount of their housing stock. In comparison, we know on the right panel that the first income quintile is mostly composed of nonbusiness households, which constitutes 95% of the income quintile. Their wealth seems to be divided evenly between the categories of housing and financial assets, which is different from the asymmetrical allocation of wealth for business households in the same income quintile.

On the left panel, the average of financial asset holding in business households is apparently in excess of that of housing asset holdings in each income group. In contrast, the right panel shows that only the highest two income groups of worker households have the ratio of financial assets to housing asset bigger than one. Besides, the total wealth (i.e., the full height of a stacked bar in Figure 3.3) of business households is larger than that of worker households within the same income quintile. Such a difference in the level of wealth between the two groups becomes even more pronounced as we look at higher income groups. Figure 3.3 shows that the saving behaviors of business households are distinct from those of wage earner households, even after controlling for household income. This phenomenon implies that the concentration of wealth doesn't simply result from the higher incomes earned by entrepreneurs. In other words, entrepreneurs are induced to save more probably by incentives beyond ordinary precautionary saving and consumption smoothing motives.

3.2 Life-cycle patterns of household wealth holdings

In this section, I estimate the age profiles of asset holdings for business and wage earner households, respectively. The outcome of the estimation is to be used for examining the match between the proposed life-cycle model and the data. I outline the statistical procedure that leads to the findings in Appendix A. The model setup and its solution to replicate the observed life-cycle profile of wealth holdings will be discussed in the next chapter.

3.2.1 Housing asset and financial wealth

To characterize the key features of household wealth holdings over the life cycle, I need to make some judgments in the first place. I reorganize the asset categories in the SCF data to form a dichotomous classification of asset items that appear in a typical household balance sheet. I define the primary residence as *housing asset*.[2] I pool business equity with financial assets as well as assets under the categories of vehicles, other residential property, and nonresidential real estate as a merged category, labeled as *financial assets*. The difference between the value of the newly-defined financial assets class and the total of household liabilities is called *financial wealth*, if the difference is positive; otherwise, the difference is simply referred to as *net financial* assets. In the subsequent analysis of this study, either the empirical or the quantitative part, housing asset and financial wealth are the only two asset classes of interest.[3] The dichotomous classification is intended to emphasize on the function of housing asset for serving as collateral for loans in the form of home equity lines of credit (HELOCs), a common household external financing device that is secured by residential property in practice. This observation justifies the assumption on the role of housing as collateralizable assets in the proposed life-cycle model.

[2] The primary residence category defined in the SCF includes mobile homes and their sites, the parts of farms and ranches not used for farming or ranching business, etc.

[3] In this analysis, all dollar amounts from the SCF are adjusted to 2013 dollars using the current methods version of the consumer price index for all urban consumers (CPIURS).

3.2.2 Entrepreneurs and wage earners

To group the SCF respondents into business households and wage earners households, I utilize the responses to occupational questions of the SCF questionnaire, including "Working now? Unemployed and looking for work last year? Work for self/someone else/other?" I assume for analysis simplicity that self-employment in the SCF is a genuine entrepreneurship, rather than other kinds of self-employment out of necessity or as a last-resort option. With this rationale in mind, I treat the self-employed as entrepreneurs for their similarity of owning a business in spite of the variation in the definition of being self-employed across government agents and academic research. I purge household samples whose head's work status is in neither of the aforementioned two work status categories.[4]

3.2.3 Synthetic cohort panel

I follow the synthetic cohort techniques described in Deaton and Paxson (1994) to construct a *pseudo panel* or *synthetic cohort panel* from the SCF cross-sectional data collected during the period 1983-2013. The reason that I skip the two official SCF panel data of the periods 1983-1989 and 2007-2009 is that these panel data are short in the time dimension, which is not suitable for drawing statistical inference on the age profile of household asset holdings under the intertwined influence of age, cohort and time effects. The implementation of the synthetic cohort techniques in the current case proceeds in two steps: The first step is to identify the age of the reference household head, I associate every household in the

[4]Self-employed people defined in the analysis include independent contractors, sole proprietors of businesses and those with partnerships in businesses. This definition of work status corresponds to the group of respondents in the SCF summary data set labeled as 2 (self-employed/partnership). In the survey of year 2013, for example, the fraction of households being purged is around 33% (a category of household in the SCF includes the retired/disabled, not working or out of the labor force, age 65 or older, and those under 65). The household-level panel generated can be adjusted to a per-adult-equivalent basis using the OECD equivalence scale, which assigns a weight of 1.0 to the first adult, 0.7 to each additional adult, and 0.5 to each child. The patterns are not noticeably different from that without the equivalence scale adjustment, so I don't include them in the report.

1983 survey with a cohort that falls in one of evenly-divided age brackets between the ages of 20 and 85 with a length of five years, starting with the 20-24 years old age group. The second step is to compute the weighted descriptive statistics of housing and financial wealth holdings based on the synthetic cohort panel. For example, for the cohort of worker households born in 1961—who were 22 years old in the year 1983—I use the 1983 survey to calculate the median housing stock for the worker households of age 22. The result forms the first data point for the worker households of cohort 1961 in 1983. The second data point of the same cohort is the median housing asset holdings of 25-year-olds (22+3) in the 1986 survey (1983+3). The rest of the data points associated with the cohort 1961 could be tracked out with the same method based on the remaining surveys of years from 1989 to 2013 until they are last observed at age 52 in the survey of year 2013. The weighted descriptive statistics of all the cohorts when the cross-sectional data are available could be obtained in the same way. They constitute the synthetic panel data which I utilize in the subsequent statistical analysis.

3.2.4 Partially linear regression

Quantitative life-cycle models in the literature typically abstract from business cycle fluctuations and cohort effects. Empirical life-cycle profiles of wealth holdings can be used to assess the performance of life-cycle simulation models in matching the data. In this study, I employ a partially linear regression model in which cohort and time (measured in years) effects are controlled for by dummy variables to extract the nonlinear relationship between the level of household asset holdings and the household head's attribute, age. This empirical exercise follows the procedure itemized in Fernández-Villaverde and Krueger (2007), which is based on the econometric techniques proposed by Robinson (1988). The procedure is outlined as the following:

First, to disentangle the intertwined influence of age, time, and cohort effects on household housing and financial wealth holdings, I estimate a partially linear regression model defined by:

$$y_{it} = constant + \sum \beta_i cohort_i + \sum \beta_t year_t + m(age_{it}) + \varepsilon_{it}, \tag{3.1}$$

where y_{it} is the level of a specific statistic of household asset holdings for cohort i in the survey of year t, the variable $cohort_i$ is a dummy for each cohort i except the oldest one, $year_t$ is a dummy for each survey year t , $m(age_{it}) = E(y_{it}|age_{it})$ is a nonlinear smoothing function of age_{it}, where age_{it} denotes the age of cohort i in the survey year t, $\{\beta_j\}$ are parameters for cohort $(j = i)$ and time $(j = t)$ effects, respectively, and ε_{it} is an independent, zero mean, random error.

To identify the separate effects of age, cohort and time in spite of the linear dependence among them, I assume that time effects are orthogonal to a time trend and that their sum is normalized to zero, by following Deaton (1997). The assumptions imply that I attribute time trends (the secular economic growth) to age and cohort effects, and use the time effects to capture cyclical fluctuations (business-cycle effects) that average to zero over the long run. The subsequent analysis of the nonlinear age profile of asset holdings is fulfilled by following the estimation procedure proposed in Speckman (1988) (see Appendix A).

3.2.5 Life-cycle patterns of asset holdings

As shown in Figures 3.4 and 3.5, the life-cycle patterns for housing and financial wealth holdings of the (median) business and worker households estimated in this study are at variance with a key prediction of the standard life-cycle model that do not account for market frictions, age-dependent utility of consumption, and home production. The conventional

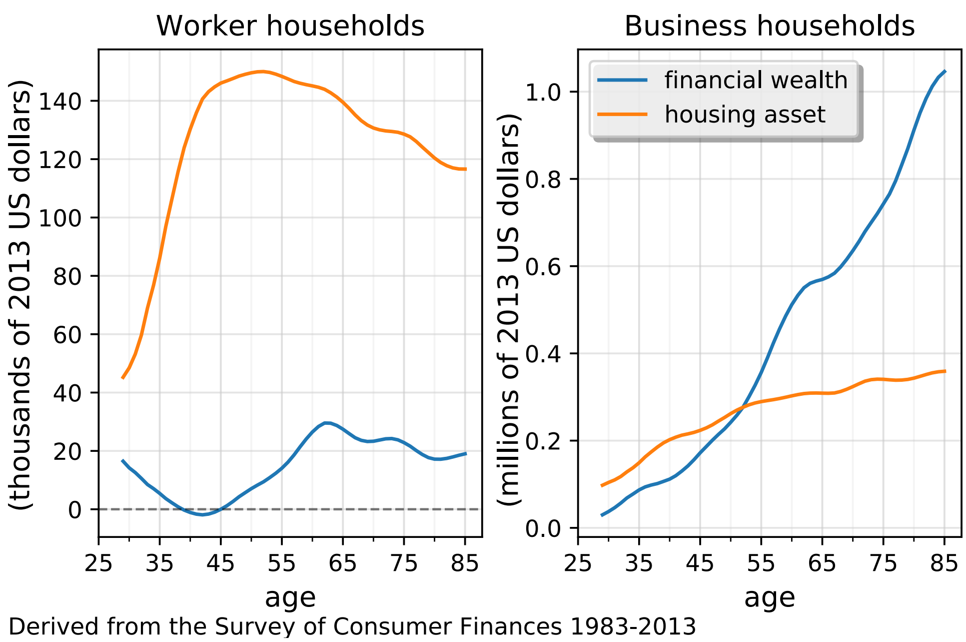

Figure 3.4: Age profiles of housing and financial asset holdings.

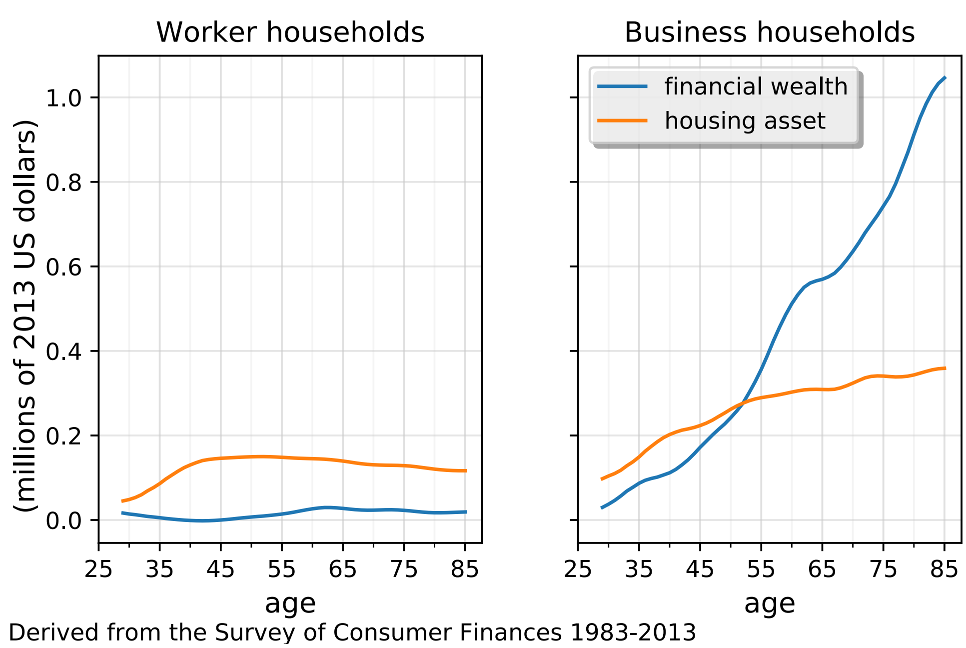

Figure 3.5: Age profiles of housing and financial asset holdings (shown at the same scale).

life-cycle theory indicates that the ratio of housing to non-housing consumption is independent of age. The trends of housing stock should follow the same pattern as financial wealth holdings. On the contrary, the age profiles of housing stock and financial wealth holdings are nonlinear for both worker and entrepreneur households, and evolve apparently in different styles throughout the lifetime.

The left panel of Figure 3.4 shows the age profile of wealth holdings for the median wage earning households. First, their housing stock starts at a higher level than the initial amount of their financial wealth holding. The former is more than twice as much as the latter. This feature conforms to the common notion that young households prefer to hold more housing stock than financial assets. In a short period of time, around their early 40s, the median wage earning households' net financial asset are turning negative, while their housing asset holding is approaching its lifetime maximum, which is over three times as much as its starting level. The negative net financial asset holding may imply that early in life the median worker households build up their housing stock by borrowing.

Second, the timing for the financial wealth holding of the median worker households hitting its lifetime maximum is about ten years later than that for the housing stock. The former takes place on the eve of retirement ages. As the median worker households enter the retirement stage of the life cycle, both of the age profiles exhibit a decreasing pattern. However, the magnitude of dissaving in terms of the percentage change is much larger for financial asset holding than for housing asset holding. At the age of 85, the financial asset holding drops by one thirds from the lifetime maximum almost back to its initial level. Conversely, the housing asset holding decreases by one fourth from 150 thousand dollars to 115 thousand dollars. One interpretation is that households face higher costs, physical and psychological, in adjusting the stock of housing than that in adjusting the holding of financial assets.[5]

In the median wage earner households, the age profile of net financial asset holding is S-shaped and that of housing stock is hump-shaped but exhibiting a flattening out pattern in the second half of their lifetime. In comparison, regardless of whether the asset type is housing or financial wealth, asset holding in the median business household grows steadily over the life cycle, as illustrated on the right panel of Figure 3.4. The significant rate of financial asset accumulation reflects the ever-growing size of business equity held by the median business households throughout the lifetime.

[5]Due to the configurational variety and the immobility of houses, potential buyers and sellers in the housing market need to put in considerable amounts of time and resources to acquire information about the value of a specific housing unit. There are implicit and explicit search costs associated with a transaction of housing assets. These encompass the opportunity costs of time associated with market search and the pecuniary costs such as brokerage and agent fees, legal fees, and origination fees. In addition, households have to move to a new house, which entails physical moving costs and psychological costs of accommodating to a new living environment.

Chapter 4

The Model Economy

Consider an overlapping generations economy populated by households who live for at most T (=14) periods, each of which is 5 years long, starting with the age of 20 years old. There are four sectors: households, production, financial intermediary, and government. Households make consumption-saving decisions: They derive utility from consuming consumption goods and housing services, and save in the form of housing asset as well as interest-bearing financial assets. Household occupations are determined at the end of the preceding period by weighing between running a business for seeking the economic rent for entrepreneurship (i.e., being an entrepreneur; a business household) or working for others in exchange for wages (i.e., being a worker; a worker household). After reaching the retirement age of T_r years old, workers are forced to retire and live on lifetime savings and social security benefits. Elder entrepreneurs of age T_r or older make the same decisions except that they can keep running a business until they choose to exit entrepreneurship permanently. At the end of each period, households (younger than T_r years old) perceive the realization of shocks to labor efficiency and entrepreneurial talent. Financially constrained households may use housing asset as collateral for borrowing money through a financial intermediary. The government consumes a fixed share of total output, collects tax revenues, and operates the social security system.

4.1 Demographics

Let t denote a point of time, and g a household head's model age in the g-th period of his/her life. In other words, the household head (or alternatively, household, for simplicity) is born (i.e. enter the model) at the first period, $g = 1$. Households face a probability p_g of surviving up to age $g+1$ conditional on being alive at age g, and could live up to age T. There is no population growth. The measure of the newborn at t equals the total measure of the deceased at $t-1$ and thus the size of the population is stable over time.

4.2 Preferences

In specific, the household i maximizes the value of expected, discounted lifetime utility derived from two distinct types of consumption flows: housing services, $\{s_{ig}\}$, and non-housing consumption goods, $\{c_{ig}\}$, over the life cycle from $g = 1$ to T. For notational simplicity, I drop the subscript i hereafter when no confusion arises. The utility function of the household takes the standard time-separable form as follows:

$$\mathbb{E}_0 \sum_{g=1}^{T} \beta^g \prod_{j=1}^{g-1} p_j \left[p_g U(c_g, s_g) + (1-p_g) q \log(d_g) \right], \tag{4.1}$$

where $U(c_g, s_g)$ is the period utility function of constant relative risk aversion (CRRA) type:

$$U(c_g, s_g) = \frac{g(c_g, s_g)^{1-\sigma}}{1-\sigma},$$

in which $g(\cdot,\cdot)$ is a constant elasticity of substitution (CES) aggregator function of the services flows from housing and non-housing consumption goods in the Cobb-Douglas form of $c_g^{1-\theta} s_g^{\theta}$. I assume there exists a linear one-to-one mapping between one unit of housing capital h_g and one unit of the derivative service flow s_g. The preference for housing services relative to non-housing consumption good is denoted by θ. The variable σ is the coefficient of relative risk aversion associated with the composite consumption goods aggregated by the Cobb-Douglas aggregator. The variable d_g represents the amount of wealth the household head bequests upon death at age g. The household discounts the future utility at rate β. The parameter q dictates the household bequest motivation, which takes the value of zero if the household has no motivation in making a bequest upon death.[1] In equation (4.1), $\mathbb{E}_0$ is the expectation operator conditional on the information available to the household at the point of time when entering into the model.

4.3 Endowment

Working-age households enter a period with an occupation that was chosen at the end of the period prior to the current one. Every choice is made with the latest perceived individual-specific information regarding labor productivity and entrepreneurial talent, both of which are drawn by chance and defined by respective stochastic processes defined below:

4.3.1 Endowment of labor efficiency

At the end of period g, households are endowed with labor efficiency of the value determined by the product of two components denoted by $\bar{e}_g$ and $\tilde{e}_g$. The former is a deterministic component associated with age to reflect the effect of working experience on

[1] q is set to 1 in the baseline model and the tax policy experiments.

labor productivity. The latter captures the impact of the labor income shocks that follow an AR(1) in logs: $\log \tilde{e}_g = \rho_e \log \tilde{e}_{g-1} + \varepsilon_{e,g}$, where $\varepsilon_{e,g}$ is a white noise process with variance $\sigma^2_{\varepsilon_e}$, and ρ_e determines the persistence of the labor income shock.

4.3.2 Endowment of entrepreneurial talent

Households are endowed with entrepreneurial talent at the end of every period, as long as they are not retired, or they are entrepreneurs but have not chosen to exit entrepreneurship. Entrepreneurial talents are related to a pool of business projects, $\mathcal{K} = \{k_0, k_1, \ldots, k_{N_k}\}$, where k_i denotes the minimum capital needed to implement the project i, which also represents the required business talent for managing the project. The variable k_0 indicates the situation that the household has no entrepreneurial idea at all. The subscripts from one to N_k refer to the size ranking of business projects in ascending order. Index 1 referring to the smallest business project and so on. The required business capital of a project is indivisible in the sense that the household either undertakes the project with sufficient funds to fully satisfy the project's capital requirement or leaves it.

4.3.3 Development of entrepreneurial talent

To embody the notion that entrepreneurs must have a basic talent before acquiring an advanced one (in other words, the entrepreneurial talent develops gradually without jump), I follow Quadrini (2000) to specify the evolution of entrepreneurial talent with the following setting: the probability of having a new entrepreneurial talent $\tilde{k}$ conditional on having had the talent k_j is positive in two cases: one is when the realization of the new talent $\widetilde{k}$ is exactly the talent for running the next-highest investment scale relative to the one employed currently k_i (in which case, $\tilde{k} = k_{i+1} > k_i$) and the other is when the development of the entrepreneurial talent stagnates such that the talent for the project currently undertaken is carried over to the next period, and as a result, $\tilde{k} = k_i$. In short, the conditional probability distribution is given by:

$$P_{k_i}(\widetilde{k}) \begin{cases} > 0 & \text{if } \widetilde{k} \in \{k_i, k_{i+1}\} \text{ and } i < N_k, \\ = 1 & \text{if } \widetilde{k} = k_i \text{ and } i = N_k, \\ = 0 & \text{otherwise.} \end{cases} \tag{4.2}$$

In the following analysis, I will restrict my attention to the case where $N_k = 1$ for computational simplicity.

4.3.4 Intergenerational transmission of labor productivity

When households die and exit the model, they are replaced by their own offspring of age one, who partially inherit their parents' labor productivity upon death dictated by an AR(1) process: $\log e_c = \rho_{ep} \log e_p + \varepsilon_{ep}$, where the subscript p indicates that the variable is associated with the parents, and the subscript c with the offspring. The variable ε_{ep} is a white noise process with variance σ_{ep}^2.

4.3.5 Inheritance of entrepreneurial talent

Based on Swedish adoption data, Lindquist, Sol, and Van Praag (2015) study the origins of the intergenerational association in entrepreneurship, and find that parental entrepreneurship increases the probability of children's entrepreneurship by about 60%. To factor this finding into the present model in a parsimonious way, I allow the entrepreneurial knowledge as well as the business condition (reflected by the momentary business shocks the parental entrepreneurs experience upon death) to be passed down to their progeny via a one-to-one direct correspondence. It is noteworthy that the model abstracts from the consideration of within-household wealth inheritance for modeling simplicity. The technical makeshift is to redistribute total unintended bequests by the government as a lump-sum transfer to the whole population alive, an assumption which is common in the literature. Yang (2009) finds that the numerical outcomes are robust regardless of how the wealth of the deceased is redistributed back to the model economy in the study of life-cycle consumption.

4.4 Production

The economy has two sectors of production for one consumption good. One sector which is referred to as the non-entrepreneurial or corporate sector is composed of firms operating in a frictionless, perfectly competitive environment typifying firms with diversified risk and anonymity of the operations. The other sector is called the entrepreneurial or non-corporate sector which comprises of entrepreneurial firms whose business activities are tied up with the owner's decisions (production factor hiring and external financing) subject to their wealth and talent (e.g., entrepreneurial talent, the amounts of housing asset and own capital). Due to non-diversifiable firm-specific risk, firms in the entrepreneurial sector face stricter liquidity constraints than firms in the corporate sector when dealing with the financial intermediary for business loans .

4.4.1 Corporate sector

The corporate sector is represented by a representative firm operating a standard Cobb-Douglas production technology: $Y_c = F(K_c, N_c) = K_c^{\alpha} N_c^{1-\alpha}$, where α is the capital income share in the corporate sector, K_c and N_c are the aggregate capital and efficient units of labor in this sector. Capital depreciates at a rate δ_k.

4.4.2 Entrepreneurial sector

Entrepreneurs run their own technology and produce output according to the production function, $y = f(k,n,z) = z(k^{\alpha}n^{1-\alpha})^{\nu}$, where k is the required capital investment for the business project, n is efficiency units of labor employed in the firm, z is a firm-specific technology shock that remains unknown at the end of the previous period when the decisions on being an entrepreneur and the amount of business loan are made. The technology shock is unobserved until the beginning of the present period. The parameter α denotes the capital income share in the corporate sector. The parameter ν determines the degree of decreasing returns to scale in capital and labor exhibited in the production function of the entrepreneurial sector. It is a parameter that captures an entrepreneur's limited span of managerial control (a fixed factor reflecting his entrepreneurial talent) when his management is gradually stretched over larger and larger projects as discussed in Lucas (1978).

The technology shock $z \in \mathcal{Z} = \{z_1, \ldots, z_{N_z}\}$ have finite states, following a first-order Markov process with project-specific transition probability $Q_k(z'|z)$. As in Meh (2005), the first element of the set $\mathcal{Z}$ is assumed to be a bad shock that is highly persistent such that $Q_k(z_1|z_1) = 1$. Consequently, if an entrepreneur receives a bad shock z_1 at the beginning of the current period, he will choose to exit entrepreneurship with which the current project k is associated. It is worth noting that an entrepreneur-turned worker still has the opportunity to re-enter entrepreneurship in the future (as long as he is not retired) because, by construction, the probability for a worker to start up a small firm from scratch is positive, $P_{k_0}(k_1) > 0$.

The amount of invested capital depreciates in a stochastic fashion based on the belief that the end-of-period value of the invested capital should be positively related to the result of the entrepreneurial activity, which is primarily governed by the realization of the technological shock. The introduction of stochastic depreciation takes into consideration the possibility of enormous losses in entrepreneurial activities. If the entrepreneur receives a good shock to production, then the residual value of the invested capital after depreciation is high, and vice versa. The depreciate rate is denoted by δ_z, a project-specific function of the shocks z.

4.4.3 Entrepreneurs' profit maximization problem

Given a business project whose capital requirement is k, the entrepreneurial household's business profit (i.e. revenue net of the cost of production factors) and labor demand is determined by solving the following profit-maximizing problem:[2]

$$\pi(a,k,z) = \max_{n} \left[z_k (k^{\alpha} n^{1-\alpha})^{\nu} + (1-\delta_z)k - (1+r_l)(k-a)^{+} - (1+\frac{\tau_{ss}}{2})wn \right], \qquad (4.3)$$

with $r_l = r_d$, if $k \leqslant a$, or $r_d + (k-a)\gamma/k$, otherwise. The variable r_l dictates the cost of capital financed from either internal or external sources. The business profit $\pi(a,k,z)$ is defined as business revenue net of labor costs (including the social security contribution) and the cost of capital externally sourced. If the amount of own business capital a (equivalent to the household's financial asset holding) is sufficient to cover the capital requirement of the business project k (that is, $a \geqslant k$), the business is entirely self-financed and the corresponding cost of capital is simply the opportunity cost r_d. Otherwise, if the scale of the investment exceeds the amount of own capital (that is, $k > a$), the business project has to be partially financed with debt and the cost of capital increases with the debt-to-capital ratio (since the intermediation cost γ is positive). Because an entrepreneur is a price taker, the

[2] I assume that entrepreneurs rely on external labor for production no matter whether their labor demand can be fulfilled by endowed labor efficiency or not. In other words, entrepreneurs always employ external labor input and earn a wage.

optimal labor demand given the realization of the technology shock z is determined by:

$$n(k,z) = \left[\frac{(1+\frac{\tau_{ss}}{2})w}{(1-\alpha)zv}k^{-\alpha v}\right]^{\frac{1}{(1-\alpha)v-1}}. \tag{4.4}$$

The resulting (ex-post) entrepreneur's profit is then given by:

$$\pi(a,k,z) = (\frac{1}{(1-\alpha)v} - 1)(1+\frac{\tau_{ss}}{2})w\left[\frac{(1+\frac{\tau_{ss}}{2})w}{(1-\alpha)zv}k^{-\alpha v}\right]^{\frac{1}{(1-\alpha)v-1}} + (1-\delta_z)k - (1+r_l)(k-a)^{+}. \tag{4.5}$$

In this economy, it is assumed that debts must be repaid to the financial intermediary sector before the payment of income taxes. This assumption is consistent with the fact that, in general, most business capital expenses are tax deductible.

4.5 Housing

Household incomes can be either consumed (c), invested in an entrepreneurial project as business capital (k), saved in a risk-free interest-bearing financial asset (a), or invested in residential capital (h). In addition, financial assets a represent loans as well. A positive amount of financial assets is a claim to the same amount of non-housing capital, while a negative amount of financial assets represent total liabilities of the size equal to the unsigned amount of the financial asset holdings.

There are no contingent claims markets for hedging idiosyncratic productivity shocks or mortality. Consumption smoothing in the economy is carried out by adjusting the levels of the financial asset holdings and the residential stock. Following Yang (2009), I consider non-convex adjustment costs of housing stock that reflects the monetary value of search, legal costs, costs of readjusting home furnishings to a new house and so on:

$$\Omega(h_t, h_{t+1}) = \begin{cases} 0 & \text{if } h_{t+1} \in [(1-\mu_l)h_t, (1+\mu_u)h_t], \\ \rho_s h_t + \rho_p h_{t+1} & \text{otherwise.} \end{cases} \tag{4.6}$$

The formulation implies that a non-zero adjustment cost of changing housing consumption is incurred only if the adjustment on the quantity of housing asset holdings is significant enough to fall outside a zero-transaction-cost range that accounts for common home renovation or normal depreciation of housing stock, in which cases no housing units change hands. I assume that transfers of residential capital between households are carried out at the end of the period. This will guarantee that housing services are enjoyed from the amount of residential stock brought into the period.

Furthermore, I assume a correspondence between the size of the houses and the consumption benefits that households derive from it. Using this residential capital, the technology for producing housing services is linear and simple. One unit of residential stock h generates one unit of service s. One important feature of housing that differentiates it from liquid financial assets is its indivisibility. To capture this property, I assume that there is a minimum house size, $\bar{h}_{min} \geqslant 0$, such that $h \geqslant \bar{h}_{min}$, as commonly seen in the literature for the lumpiness of housing. Besides, to buy a house, households must satisfy a minimum down payment requirement as a fraction λ of the house value. The role of housing as collateral for loans is discussed in the next subsection.

4.6 Financial intermediary

The financial intermediary sector consists of competitive banks, which collect deposits from households with positive balance by paying the interest rate r_d and lend the proceeds to households and firms that need a loan. There is an intermediary cost γ incurred for every unit of funds intermediated to households who undertake entrepreneurial activities, while loans made to workers or firms that produce in the corporate sector use no resources and incur no extra cost except r_d per unit of borrowings. Competition among banks makes intermediation profit zero. This assumption implies that the lending rate equals r_d for loans to the corporate sector and workers, and as mentioned above, $r_l(k,a) = r_d + (\frac{k-a}{k})^+\gamma$ for loans to entrepreneurs who are running a risky business project of scale k with insufficient internal funds of size a.

Households can borrow up to a maximum amount, which depends on the lending policy of the intermediaries. This lending policy consists of lending up to the amount that the borrower will be able to repay with certainty at the end of the next period. If an entrepreneur plans to devote k units of capital in the business project, then the minimum business income at the end of the present period before paying back the debt, is given by:

$$B_{min}(k) = \max_n \left[z_{min}(k^\alpha n^{1-\alpha})^v - (1+\frac{\tau_{ss}}{2})wn \right] + (1-\delta_{z_{min}})k, \tag{4.7}$$

where $B_{min}(k)$ denotes the business income of the project k when the realization of the technology shock takes the minimum value z_{min} (the worst technology shock), the variable w denotes the wage rate for one unit of labor efficiency, n stands for the efficiency units of labor to be employed, τ_{ss} is the tax rate for social security contribution, half of which is matched up by the entrepreneur as practiced in the U.S., and $\delta_{z_{min}}$ is the depreciation rate of capital for the project k given the shock z_{min}.[3]

To derive the limit imposed on net financial asset position a, it is assumed that $k > a$, that is, the household's own fund is inadequate for undertaking the project k without having access to external funding. It implies that the applicable interest rate is the lending rate r_l,

[3] Note that for $k = 0$ (i.e. a worker or retiree), $I_{min}(0) = 0$.

which varies with the amount of external funds $k-a$. Given this assumption and the lending policy of the bank, the payment for paying back the one-period loan, $(1+r_l)(k-a)$, must be less than or equal to the amount of the minimum business income plus incomes from other sources (such as labor income or social security benefits) and the value of housing asset (collateral for the loan). More precisely, the lower bound imposed on the net financial asset position of the household of age $g+1$ is given by

$$a_{g+1} \geqslant k_{g+1} - \left[(1-\lambda)h_g + \frac{B_{min}(k_{g+1}) + X_{next}}{1+r_l}\right], \tag{4.8}$$

where $(1-\lambda)$ represents the maximum fraction of the housing stock currently owned against which the household can borrow and $X_{next} \equiv (1-\frac{\tau_{ss}}{2})w\tilde{e}_{g+1}\bar{e}_{g+1}\mathbb{1}_{\{g+1<T_r\}} + b\mathbb{1}_{\{g+1\geq T_r\}}$ denotes incomes of the household of age g+1 in the next period from any sources other than their own businesses, and $\mathbb{1}_{\{A\}}$ is the indicator function, which takes the value of 1, if statement A attached to it is true, and 0, otherwise. That the constraint involves the value of the housing asset currently owned (h_g), rather than the house the household will buy (h_{g+1}), makes the loan resemble a HELOC rather than a mortgage, because a HELOC is a loan that uses the house currently owned as collateral for whatever expenses the household wants to finance. In short, $(1-\lambda)$ denotes the maximum fraction of the housing asset against which households can borrow in the form of a HELOC.

The borrowing constraint (4.8) is also applicable to worker households. In the event that $k_{g+1}=0$ (worker), the level of loans the household can make is bounded above by the sum of collateral and the discounted value of the next-period labor income, $(1-\lambda)h_g + \frac{w\tilde{e}_{g+1}\bar{e}_{g+1}}{1+r_l}$. In the same vein, the maximum level of loans a retiree can borrow reduces to $(1-\lambda)h_g + \frac{b}{1+r_l}$, where b denotes the social security benefits the retiree will receive.

4.7 Government

The government is engaged in the following activities: collecting tax revenues to finance the public expenditure G, paying interests on the government debt, and implementing a self-financed pay-as-you-go social security system. The government expenditure is exogenously given as a fixed fraction of total output. A balanced budget is imposed at every point of time. In the baseline model, the government levies progressive taxes on total income. Following Cagetti and De Nardi (2009), I allow the tax schedules to be different for entrepreneurs and non-entrepreneurs (including workers and retirees) and adopt the functional form proposed by Gouveia and Strauss (1994) that assume the total taxes $\mathcal{T}_i(X)$ on the household's total income X is given by:

$$\mathcal{T}_i(X) = a_{i,0}\left[X - (X^{-a_{i,1}} + a_{i,2})^{-1/a_{i,1}}\right] + \tau_{st}X, \tag{4.9}$$

where X is the taxable income of the household, τ_{st} captures state taxes or transfer proportional to the taxable household income, and the subscript could be indexed by $i = e, w$ for entrepreneurs and workers, respectively. τ_{st} is endogenously determined in the stationary equilibrium such that the government budget is balanced. The set of parameters $\{a_{i,j}\}_{i=e,w,j=1,2,3}$ are estimated from microeconomic data.

The government runs a simple social security program which collects payroll taxes from labor income at the rate τ_{ss}. All the proceeds are equally distributed to all the retired agents. Since the amount of benefits is the same for all households regardless of the amount they contributed in the working stage of lifetime, this particular social security program, as pointed out in Huggett (1996), has a strong redistribution effect as does the U.S. Social Security program, for the reason that the value of social security benefits received by low (high) income household is greater (smaller) than the amount of social security contributions they made in the working stage of lifetime.

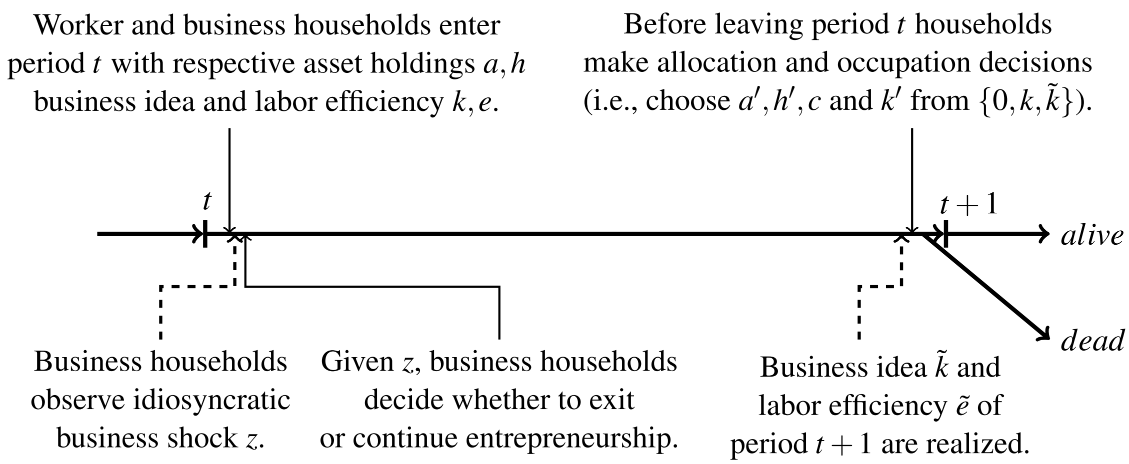

Figure 4.1: Timeline of events.

4.8 The household's optimization problem

A household enters a period with the knowledge of a, h, k, and e. The work status of the current period (or equivalently, the business project to be implemented, k) is determined in the preceding period. Figure 4.1 illustrates the timeline of events. A dashed line indicates the outcome of the event is determined by luck. The household head faces a mortality shock by the end of period t, which determines whether he/she will live through period $t+1$ or die. This random event is represented by the biforked solid line.

4.8.1 The timing of events

At the beginning of each period, entrepreneurs perceive the realized level of the firm-specific technology shock z, and decide whether to exit entrepreneurship, or alternatively, how much units of labor efficiency, n, to hire for starting up or continuing their businesses. Workers simply rent out their labor efficiency for a wage. Labor and capital are supplied to firms in both of the production sectors, and production takes place. During retirement households receive social security benefits.

At the end of each period, working-age household heads observe the realization of a pair of individual-specific shocks (labor productivity $\tilde{e}$ and entrepreneurial talent $\tilde{k}$), while elder entrepreneurs perceive only the realization of the latter. Knowing the set of projects in their reach (that is, the entrepreneurial talent currently implemented, k, and the newly-acquired entrepreneurial talent, $\tilde{k}$), working-age agents weigh between working for others and running a business project chosen from the project pool, $\{k, \tilde{k}\}$. Elder entrepreneurs decide whether to retire or continue running their businesses. Regardless of work status, households then determine how much to save by adjusting the levels of housing stock and the financial asset holdings, and how much to leave for consumption. Finally, uncertainty about early death is revealed.

4.8.2 Recursive formulation of the household's optimization problem

Before defining the stationary equilibrium, it is useful to write the agent's problem in recursive form. The state of a household at the beginning of a period after the realization of the technology shock is described by six state variables: age (g), labor productivity (e), net financial asset holdings (a), housing stock (h), the business investment (k), and the technology shock to his production (z). Recall if $k = k_0$ the household head is a worker or a retiree; if not, an entrepreneur. Households are price takers in the goods and factor markets. I normalize the price of the consumption good to 1. Accordingly, r_d and r_l are real interest rates; w are real wages.

For notation simplicity, I refer to as $\mathcal{S}_g \equiv \{g, a, h, k, z, e\}$ the state variable set that captures the full information about a household at the beginning of period g, and refer to the set of state variables that characterize the household at the end of the period of age g as $\widetilde{\mathcal{S}}_g \equiv \{g, a, h, k, z, e, \tilde{k}, \tilde{e}\}$. Note that $\widetilde{\mathcal{S}}_g$ is simply an augmented set from $\mathcal{S}_g$ with information not realized until the end of the period: the entrepreneurial talent $\tilde{k}$ and the shock to labor efficiency $\tilde{e}$. In order to further simplify notation, I drop subscripts g and use a prime on a variable to indicate its value in the next period.

The households' utility maximization problem at the end of age g, after observing the realization of the idiosyncratic shocks $\tilde{k}$ and $\tilde{e}$, can be formulated recursively as:

$$\tilde{V}(\widetilde{\mathcal{S}}_g) = \max_{a', h', k'} \left[\frac{(c^{1-\theta} h^{\theta})^{1-\sigma}}{1-\sigma} + \beta(1-p_g) q \log(d) + \beta p_g \sum_{z'} V(\mathcal{S}_{g+1}) Q_{k'}(z'|z) \right], \quad (4.10)$$

subject to

$$\begin{aligned} c = {} & (1+r_d) a \mathbb{1}_{\{i=w\}} + (1+r_d)(a-k)^{+} \mathbb{1}_{\{i=e\}} + (1-\delta_h) h + \pi(a,k,z) \\ & + (1 - \frac{\tau_{ss}}{2}) w \tilde{e} \bar{e} \mathbb{1}_{\{g<T_r\}} + b \mathbb{1}_{\{g \geq T_r\}} + \zeta - a' - h' - \Omega(h,h') - \mathcal{T}_i(X), && (4.11) \\ a' \geq {} & k' - [(1-\lambda) h + \frac{B_{min}(k') + (1 - \frac{\tau_{ss}}{2}) w \tilde{e}' \bar{e}' \mathbb{1}_{\{g+1<T_r\}} + b \mathbb{1}_{\{g+1 \geq T_r\}}}{1+r_l}], && (4.12) \\ h' \geq {} & \bar{h}_{min}, \quad c > 0, \quad d \geqslant 0, \quad k' \in \{0, k, \tilde{k}\}. && (4.13) \end{aligned}$$

with $X = r_d a \mathbb{1}_{\{a>k\}} + \pi(a,k,z) + (1 - \frac{\tau_{ss}}{2}) w \tilde{e} \bar{e} \mathbb{1}_{\{g<T_r\}} + b \mathbb{1}_{\{g \geq T_r\}}$, $d \equiv a' + h + \geqslant 0$, and $i = e$, if $k > 0$ or w, otherwise. $\mathbb{1}_{\{A\}}$ stands for an indicator function taking the value of unity when the event A is true. $V(\mathcal{S}_g)$ denotes the household head's value function at the beginning of age g. $\tilde{V}(\widetilde{\mathcal{S}}_g)$ denotes the value function at the end of age g. In the period budget constraint, equation (4.11), X stands for the amount of the household taxable incomes, ζ is the lump-sum unintended bequest redistribution, and b is the Social Security benefits. The household's optimization decision is subject to the budget constraint (4.11), a borrowing constraints (4.12) and a non-negative bequest constraint. In addition, the household total income X is defined as the sum of the return on savings $r_d a$, business profit $\pi(a,k,z)$, labor income net of social security contribution (if the household head is in the working-age stage of lifetime) $(1-\frac{\tau_{ss}}{2})w\tilde{e}\bar{e}$, and social security benefits (if the household has been retired) b. The solution is given by the policy functions of the next period's financial asset holding $g_a(\widetilde{\mathbb{S}}_g)$, housing asset holding $g_h(\widetilde{\mathbb{S}}_g)$, and the business investment $g_k(\widetilde{\mathbb{S}}_g)$.

The value function at the beginning of the period is the expected value of the end-of-period value function, $\tilde{V}$, conditional on the information available at the beginning of the current period:

$$V(\mathbb{S}_g) = \sum_{\tilde{e},\tilde{k}} \tilde{V}(\widetilde{\mathbb{S}}_g)P_k(\tilde{k})\Gamma(\tilde{e}|e), \tag{4.14}$$

where Γ is the transition probability of the first-order Markov process approximating the logarithm of labor income shock AR(1) process, $\log\tilde{e}$, using the techniques given in Tauchen (1986) with $\Gamma(\tilde{e}|e)$ being the transition probability from the current state e to the next state $\tilde{e}$. $P_k(\tilde{k})$ is the conditional probability distribution concerning the evolution of entrepreneurial talent defined above.

4.9 Definition of stationary equilibrium

The distribution of households with respect to individual states $\mathbb{S}_g$ for age group g at time t is denoted by the measure $\mu_g^t(\mathbb{S}_g)$. Because the economy does not feature aggregate shocks, I can appeal to the law of large numbers to ensure that, in any stationary equilibrium, prices including wages and the interest rates are not functions of distribution of households, and the distribution μ is invariant over time.

Definition. Given a fiscal policy regime $\{G, \tau_{ss}, \mathcal{T}_{i=e,w}(\cdot)\}$, a stationary equilibrium for the model economy consists of aggregate capital and labor demands in the corporate sector $\{K_c, N_c\}$, relative prices of labor and capital $\{w, r_d\}$, a lump-sum distribution of unintended bequests ζ, an endogenous state tax rate τ_{st}, a set of value functions $\{V(\mathcal{S}_g), \widetilde{V}(\widetilde{\mathcal{S}}_g)\}_{g=1}^{T}$, individual decisions rules $\{g_a(\widetilde{\mathcal{S}}_g), g_h(\widetilde{\mathcal{S}}_g), g_k(\widetilde{\mathcal{S}}_g)\}_{g=1}^{T}$, entrepreneurial-sector firms' decision rules $n(k,z)$, and age-dependent (but time-invariant) measures of households $\{\mu_g(\mathcal{S}_g)\}_{g=1}^{T}$, such that:

1. Given the prices and the government policy, consumers maximize utility and entrepreneurs maximize business profits.

2. The marginal product of labor and the marginal product of capital (net of depreciation) in the corporate sector are equal to w and r_d: $w = (1-\alpha)K_c^{\alpha}N_c^{-\alpha}$, and $r_d = \alpha K_c^{\alpha-1}N_c^{1-\alpha} - \delta_k$.

3. Market clearing conditions are satisfied: Aggregate financial asset holdings equals total capital employed in the noncorporate and corporate sectors plus government investment, and the aggregate labor input equals the labor efficiency summed over the population.

4. The government budget balances: Total tax revenues collected equal government expenses G (including government purchases G_p and government debt services G_i). social security taxes are sufficient to cover the benefits paid to agents in retirement.

5. The amount of bequests equals the amount of inheritance received by people alive.

6. Distributions are consistent with individual behavior: The distributions, $\{\mu_g\}_{g=1}^{T}$, follow

$$\mu_{g+1}(B) = \int_{\mathcal{M}} P_g(m,B)\, d\mu_g, \tag{4.15}$$

Table 4.1: Parameters calibrated with moment-matching exercises.

	Data		Model
Parameter	Target	Value	Value
Entrepreneurial sector			
k_1	Share of capital used by entrepreneurs	30%	27%
$P_{k0}(k_1)$	Share of entrepreneurs	12%	14%
$\bar{z}$	Share of income earned by entrepreneurs	30%	35%
ϕ_1	Ratio of median wealth of entrepreneurs to workers	8.0	8.1
Preferences			
β	Ratio of financial assets to housing asset	1.2	1.5
θ	Assets owned by entrepreneurs	40%	30%

for $g = 1, ..., T-1$ and for all $B \in \mathscr{B}(\mathcal{M})$ where $\mathcal{M}$ represents the space of state variables $\{a, h, k, z, e\}$, $\mathscr{B}(\mathcal{M})$ is the Borel σ-algebra on $\mathcal{M}$, P_g is the law of motion generated by the exogenous transition probabilities of $\{k, z, e\}$ and the policy functions, $\{g_a(\widetilde{\mathbb{S}}_g), g_h(\widetilde{\mathbb{S}}_g), g_k(\widetilde{\mathbb{S}}_g)\}$.

4.10 Calibration

In this subsection I describe the parameters used in the baseline model that bears the similarity to the U.S. economy. The model period lasts for five years, and correspondingly, parameter calibration is made on a five-year basis, if appropriate. Six parameters are determined endogenously in the stationary equilibrium in that six macro statistics observed in the U.S. economy are simultaneously matched by their counterparts that are computed in the stationary equilibrium of the baseline model. The rest of model parameters are set up by referring to the values commonly adopted in the literature. The computational procedure used to compute the stationary equilibrium is described in Appendix B.

Table 4.2: Parameters for demographics, preferences and endowment.

Parameter		Calibration
Demographics, preferences and endowment		
$\{p_g\}_{g=1}^{14}$	Survival probability	see text
σ	Relative risk aversion	2.0
ρ_e	Persistence of labor efficiency process	0.85
$\sigma_{\varepsilon_e}^2$	Innovation of labor efficiency process	0.3
$\bar{e}_{g=1}^{14}$	Age-labor efficiency profile	see text
Production		
α	Capital income share in corporate sector	0.25
ν	Degree of return to scale in noncorporate sector	0.9
δ_k	Annual depreciation rate of capital	10.9%
δ_h	Annual depreciation rate of housing stock	1.7%
$(\delta_{z_b}, \delta_{z_g})$	Depreciation of business capital	(0.88,0.44)
z_g	Good business shock to technology	see text

Table 4.3: Parameters for housing markets, intermediary and government.

Parameter		Calibration
Housing markets and financial intermediary		
γ	Financial intermediation cost	5.5%
$\bar{h}_{min}$	Minimum consumption of housing services	0
(ρ_s, ρ_b)	Transaction costs of houses	(7%,2.5%)
(μ_l, μ_u)	Range of no-costs housing stock change	(7%,7%)
λ	Down payment rate	15%
Government policy		
G_p	Consumption of goods and services	18.7% of GDP
G_d	Debt services	3% of GDP

The parameters to be calibrated are divided into two groups. One group is related to the household's preference, including the discount factor, β, and the relative value of the utility from housing services, θ. Their calibrations are made through matching the following data targets with their model counterparts: the ratio of aggregate financial wealth to aggregate housing stock, and the fraction of total assets owned by entrepreneurs. According to the National Income and Product Accounts (NIPA), the average value for the period 2002-2006 of private housing capital relative to total output is 1.29, and the same statistic for non-housing capital of the same period of time is 1.47. The implied ratio of financial capital stock to housing capital stock is around 1.2. The target value for the share of entrepreneurial assets is 40%; see Nakajima, 2010. The other group of parameters concerning entrepreneurial activities, including the size of the smallest business project, k_1; the probabilities of acquiring entrepreneurial talent for managing the project k_1, $P_{k0}(k_1)$; the conditional probability of drawing consecutive good business shocks in row, ϕ_1; and the average value of idiosyncratic productivity shock ($\bar{z}$). These parameters are pinned down altogether by matching the following four model aggregates with their data counterparts: the share of income earned by entrepreneurs should be 30% (see Kitao, 2008); the ratio of median wealth of entrepreneurs to workers is 8.0 (see Kitao, 2008); the fraction of capital used in the entrepreneurial sector is 0.3, as reported in Quadrini (2000) and Gravelle and Kotlikoff (1995); and the fraction of entrepreneurs in the population is 12%, which is widely accepted in the literature. Table 4.1 summarizes the parameters which should be calibrated with moment-matching exercises.

The remaining model parameters are pinned down by referring to the values commonly used in the literature. Tables 4.2 and 4.3 list this group of parameters by categorizing them into two groups: one group is pertaining to the setup of demographic structure, the production sectors, and labor efficiency endowment, while the other is about the environment setting of the housing market, financial intermediary, and the government sector.

4.10.1 Demographics and preferences

New-born household heads enter the economy at the age of 20. They are exposed to a positive mortality probability after the retirement age of 65. For computational feasibility, I set the maximum lifespan to 85 years. As a result, household exit the model for sure upon turning 90. Over the life cycle, there are $T = 14$ periods (a model period is set to be 5 years long), and the retirement stage of life starting from period $T_r = 10$. The survival probabilities $\{p_g\}_{g=1}^{T}$ are taken from the life table in Social Security Administration (2007).

The relative risk aversion coefficient σ is assumed to be 2.0, below the upper bound of 10 considered plausible by Mehra and Prescott (1985). The parameter θ which measures how much the household values consumption of housing goods relative to consumption of others is set to match the relative size of the housing and non-housing capital stock in the stationary equilibrium. The other preference parameters include the discount factor β, which is calibrated such that the ratio of the aggregate amount of wealth to total output in equilibrium matches its U.S. counterpart.

4.10.2 Labor efficiency endowment

The deterministic age-profile of labor productivity $\{\bar{e}_g\}_{g=1}^{T}$ is taken from Hansen (1993) based on the Current Population Survey (CPS). The persistence ρ_e and variance σ_e^2 of the stochastic productivity process are estimated from the Panel Study of Income Dynamics

(PSID) data by Altonji and Villanueva (2002).[4] The persistence coefficient of the labor productivity inheritance process, ρ_{ep}, is taken from Zimmerman (1992), based on the National longitudinal Survey (NLS), which measures the amount of intergenerational economic mobility in the United States, and the residual variance σ_{ep}^2 is taken from De Nardi (2004).[5]

4.10.3 Shock to business production

I assume that there are three types of business projects in the model economy, characterized by respective minimum capital requirement $\{k_1, k_2, k_3\}$. The production technology employed in the corporate sector is distinguished from its counterpart in the entrepreneurial sectors.

Given a project that embodies the entrepreneurial idea k (equivalently, a project of size k), the technological shock z is assumed to take two values, $z_{g,k}$ and $z_{b,k}$, which stands for good shock and bad shock, respectively. The shock follows a first-order Markov process with a transition probability matrix $Q_k(z'|z)$:

$$Q_k(z'|z) = \begin{pmatrix} 1 & 0 \\ 1-\phi_k & \phi_k \end{pmatrix}, \text{ for } k = k_1, k_2, k_3, \tag{4.16}$$

[4]The parameters are aggregated into 5 years in order to be consistent with the model period. Since retirement begins at the model age T_r, the deterministic term of labor productivity equals zero for agents of age T_r or older.

[5]I set the possible realizations of the first-order Markov chains converted from the initial inherited labor productivity process (e_c) to be identical with the possible realizations of the lifetime labor productivity process ($\tilde{e}_g$).

where, for the project of size k, ϕ_k denotes the conditional probability of receiving yet another good technology shock in succession. The calibration of $\{\phi_j\}_{j=1}^3$ is to have model-generated exit rates from entrepreneurship for agents with different levels of business experience to match the counterparts in the real world. Following Quadrini (2000), the probabilities are set as follows: $\phi_{k_1} = 0.75$ for the smallest project, $\phi_{k_2} = 0.92$ for the mid-sized project, and $\phi_{k_3} = 0.97$ for the largest project. The justification behind this probability setting is that, first, as argued in Quadrini (2000) based on the PSID data, the exit rate from entrepreneurship decreases with entrepreneurial tenure.[6] Second, households running larger businesses have higher entrepreneurial tenure; see Quadrini (1999). Hence, smaller projects should be assigned larger probabilities of exiting entrepreneurship. This calibration process gives an average exit rate from entrepreneurship of 0.20.

To determine the specific values of the technological shock for the business projects, I assume that the bad technology gives rise to zero production for all the projects (that is, $z_{b,k} = 0$ for $k = k_1, k_2, k_3$), and that the average of the technological shock $\bar{z}$ to entrepreneurial projects is identical across all entrepreneurs. Therefore, given $\bar{z}$ and the project-specific conditional probabilities of receiving another good shock in row, ϕ_k, the magnitude of the good shock, $z_{g,k}$, can be derived from the following equation: $z_{g,k} = \bar{z}/\phi_k$, for $k = k_1, k_2, k_3$.

4.10.4 Entrepreneurial talent

Given a business project of size k, the probability distribution that translates the entrepreneurial learning process—$P_k(\tilde{k})$, where $k \in \{k_0, k_1, k_2, k_3\}$—are set endogenously such that the distribution of entrepreneurs in the stationary equilibrium of the baseline

[6] Quadrini (2000) reports that the exit rates from entrepreneurship are 0.447 , 0.308 , and 0.134 for business owners with one year, two years, and three or more years of entrepreneurial tenure, respectively.

model equals the imposed distribution of entrepreneurs among the three projects in ascending order of their size: 60, 30, and 10 percent. In the baseline model, the size of available business project is reduced to only one, so there leaves $P_{k0}(k_1)$ to be set.

4.10.5 Production technology of the corporate sector

The production function in the corporate sector is the standard Cobb-Douglas type with the share of income that goes to non-housing stock of capital, α, being set at 0.255, an average of the same parameter estimated by Yang (2009) and Nakajima (2010) based on National Income and Product Accounts (NIPA) and the Fixed Assets Tables. As for the parameter ν that determines the degree of returns to scale in the entrepreneurial sector, I set it at 0.9, which suggests that the share of output retained as rents by entrepreneurs is 0.10.[7]

4.10.6 Depreciation

The calibration of the stochastic depreciation rate, δ_z, is made under the following assumption: the average depreciation rate for each project, conditional on survival, equals the aggregate depreciation rate of non-housing capital, δ_k, and regardless of the investment amount, the depreciation of invested capital for a project that receives the bad productivity shock is $\delta_{z_{b,k}} = 0.15$. Based on this assumption, the depreciation value pertaining to a good technology shock is then determined by the following equation:

$$\delta_{z_{g,k}} = \frac{\delta_k - (1-\phi_k)\delta_{z_{b,k}}}{\phi_k}, \text{ for all } k = k_1, k_2, k_3, \tag{4.17}$$

where ϕ_k is the conditional probability of a good shock defined above.

[7] Empirical study finds that capital and labor shares are relatively constant across countries and over time, with labor shares around 0.65–0.70 and capital shares are around 0.20–0.25. These figures imply that entrepreneurial returns could be in the neighborhood of 0.10 of output, which corresponds to a value of ν=0.90.

The annual depreciation rates of aggregate non-housing capital, δ_k, and housing capital, δ_h, are set at 9.4% and 1.7%, respectively, both of which are roughly the average of estimates commonly seen in the literature.[8]

4.10.7 Housing

Based on the house value reported by homeowners in the 1992 wave of the PSID survey, Cocco (2005) finds that the first, fifth, and tenth percentiles of reported house value distribution are 2937, 11380, and 22026 US dollars, respectively. He argues that the surprisingly low house value reported in the lower tail of distribution may be contaminated by reporting errors and thus set his model's minimum house value to be twenty thousand US dollars, which I use for $\bar{h}_{min}$ in the baseline model.

As in Yang (2009), the calibration of the non-convex costs for housing stock adjustment is made by setting the parameters prescribing the zero-adjustment-cost range to be five times the annual depreciation rate of housing capital (that is, $\mu_l = \mu_u = 5\delta_h \approx 7\%$). I set the selling and purchase costs per unit of housing asset, ρ_s and ρ_b, to be 7% and 2.5%, respectively, based on the finding from the Consumer Expenditure Survey (CEX) in Gruber and Martin (2003) that the median household spends 7 percent of a house's value to sell it and 2.5 percent to own it.

4.10.8 Financial intermediary

Diaz-Gimenez *et al.* (1992) document the average interest rates paid on several types of household borrowing and lending to banks and other intermediaries, and calibrate on the basis of these data the interest rate spread at 5.5%. I use the same value for the model

[8]For example, the rate of non-housing capital depreciation ranges from 1% in Cocco (2005) to 4.3% in Silos (2007), while the depreciation rate of housing capital ranges from 5.9% in Yang (2009) to 10.9% in Nakajima (2010).

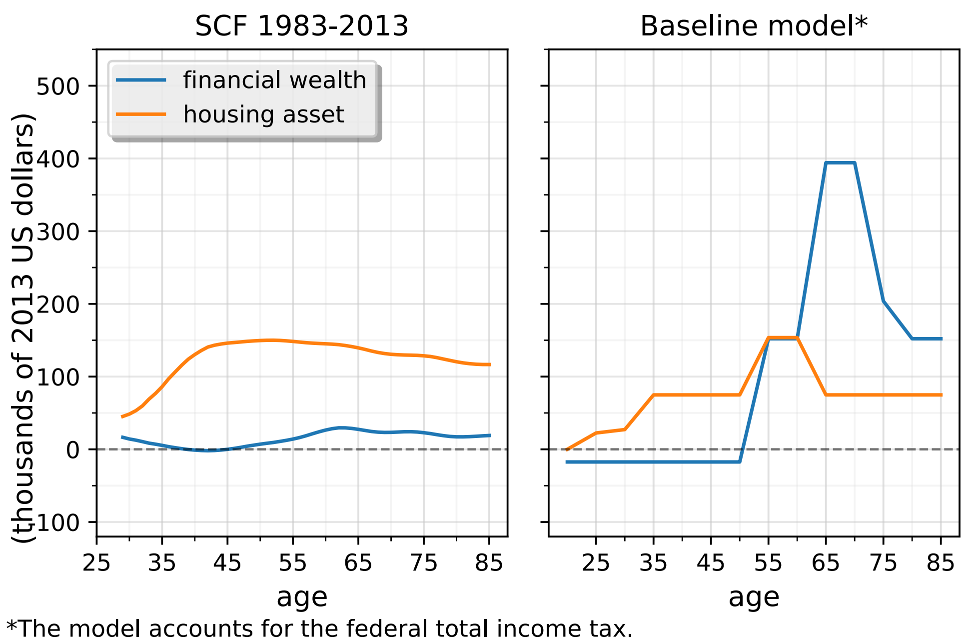

Figure 4.2: Age-wealth profiles of the median worker households.

interest rate spread, γ, and have the risk-free interest rate, r_d, be determined endogenously. Furthermore, reasonable values for down payment are between 10 and 20 percent, so I set λ to be 0.15.

4.10.9 Government policy

The calibration of the set of parameters $\{a_{i,j}\}_{i=e,w,j=1,2,3}$ in the tax function on total income for entrepreneurs and non-entrepreneurs is made by following the results of Cagetti and De Nardi (2009), who estimate the progressive tax schedule of the U.S. federal income tax based on PSID data for 1989. The tax rate that captures state and other income taxes, τ_{st}, is determined endogenously such that the government budget balances in equilibrium. The labor income tax rate, τ_{ss}, is also pinned down endogenously such that the social security contribution paid by workers and entrepreneurs equals the benefits received by the elder.

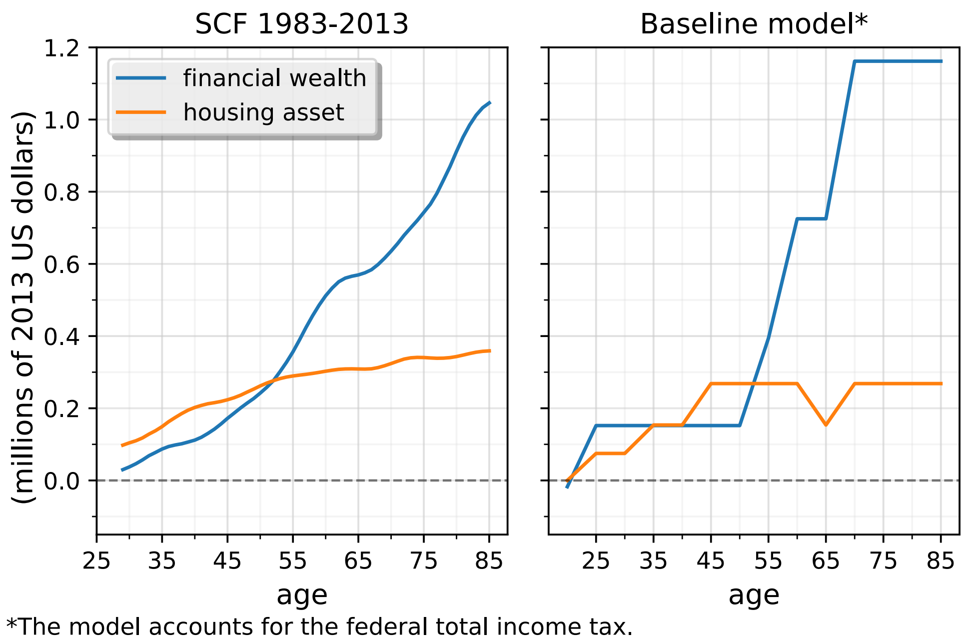

Figure 4.3: Age-wealth profiles of the median business households.

The ratio of public expenditure to output is set at 18.7 percent. This was the average ratio of government purchases to GDP over the 1990-1999 period. The level of government debt as a fraction of output is calibrated such that in equilibrium total interest payments on government debt equal 3 percent of output.

4.10.10 The calibrated baseline model

In Table 4.1 I show the model calibrated values of target moments in comparison with their counterparts. In the baseline model where the nonlinear federal income tax scheme and the endogenously determined state tax are implemented alone, the share of capital used by entrepreneurs is 27% (versus 30% in the data); the share of entrepreneurs is 14% (versus 12% in the data); the share of income earned by entrepreneurs is 35% (versus 30% in the data); the ratio of median wealth of business households to worker households is 8.1

(versus 8.0 in the data); and the ratio of financial assets to housing asset is 1.5 (versus 1.2 in the data). The values of model moments all fall in the vicinity of their target moments in data except for the dimension with respect to the fraction of assets owned by entrepreneurs (30% in model versus 40% in data).

In Figures 4.2 and 4.3 , I compare the age profiles of household asset holdings with their counterparts in the data by the occupation of household heads. In Figure 4.2, we can find that there exists a discrepancy between the model and the data in the financial wealth holdings over the second half of the median worker household's life cycle. This problem implies that the current parameter setting may be not in the neighborhood of the optimal one. A more extensive and refined search in the parameter space would fix the disconformity. In addition, the mismatch might be attributable to the dichotomous classification of households by occupation. In the model, there coexist three types of households---the self-employed, the retired, and wage earners. The last two subgroups of households are pooled together as the group of work households in the model. In the data, however, subgroups, like the retired, students, and the unemployed, are dropped in the very beginning of the data cleaning stage because the model doesn't account for unemployment and it abstracts from the occupational status such as students. Consequently, this accounting exercise adopted in the model might lead to a divergence in the pattern of wealth holdings between the model and the data, especially over the retirement sage of life cycle. However, the s-shaped age profile of financial asset position that is featured in the data is still captured by the baseline model: in the early stage of model life the model financial asset position of the median worker households is negative, then increasing by age of 45, reaching its lifetime maximum around the retirement age 65, and declining apparently during the retirement. Besides, the dual climaxes hit by financial and housing asset holdings in model are shown in tandem following the correct order observed in data: the lifetime high hit by financial asset position shows up much later than that hit by housing asset holdings. The former appears around age of 65, while the later takes place much earlier in life. In contrast, as shown in Figure 4.3, the model generated life cycle patterns of asset holdings closely mimic their counterparts in data for business households, with respect to relative scale and the shape of life cycle trajectory.

Chapter 5

The Computational Experiments

At the end of the last chapter, I obtained a calibrated model of the U.S. economy where the main tax revenues come from a progressive tax on household total income. In the first policy experiment of this chapter, I introduce a flat capital income tax into the calibrated model and call the resulting economy as the baseline economy. The amount of government spending in the stationary equilibrium of the baseline economy is to be computed and retained in all the policy experiments regardless of the change of tax policies. By doing so, I execute all the counterfactual tax policy reforms in a revenue-neutral style.

For the expositional convenience, I denote a tax scheme as $\mathcal{T}^p$, where the superscript indicates that this experimental tax scheme is introduced in the tax reform for the p-th policy experiment. Further, I denote the corresponding economy that ends up with the implementation of the experimental tax scheme as $\mathcal{E}^p$. For example, I denote the baseline economy by $\mathcal{E}^1$. For expositional convenience, I denote the calibrated model of the US economy by $\mathcal{E}^0$. In the end of this chapter, I will remove model elements like housing or entrepreneurs one at a time from the basic model environment defined above to conduct derived analysis from the original one equipped with full model elements, for the purpose of justifying the significance of housing and entrepreneurs for matching the wealth distribution generated by model simulation with that observed in the data.

5.1 Taxes on capital income and wealth

In the first policy experiment, a capital income tax that is imposed on the interest accrued from savings accounts is introduced into the calibrated model of the US economy, $\mathcal{E}^0$. In the meantime, business profits are still counted toward total taxable income under the nonlinear total income tax scheme of $\mathcal{E}^0$. Note that the taxes other than the nonlinear income tax is still in effect for equating government revenues to government spending in steady state. It is also noteworthy that a household's labor income, social security benefits, and any lump-sum transfer redistributed by the government are subsumed under household taxable income. The resulting tax schedule, $\mathcal{T}^1$, a modification of the one defined in Section 4.10, is given by

$$\mathcal{T}_i^1(X_{bp}, X_{sv}, X_1) \quad = \quad a_{i,0}\left[X_1 - (X_1^{-a_{i,1}} + a_{i,2})^{-1/a_{i,1}}\right] + \tau_{sv}X_{sv} + \tau_{st}X_1, \tag{5.1}$$

where the subscript 1 indicates that the variable in the formula is used for the economy $\mathcal{E}^1$ where the experimental tax scheme $\mathcal{T}^1$ is introduced, and the subscript i indicates the occupational status of households. The variable, $X_{sv} \equiv \max[r(a-k), 0]$, denotes the capital income earned from savings, where a is the level of financial wealth, probably taking negative value when the household is in debt. X_1 stands for taxable incomes under the nonlinear income tax scheme and is given by:

$$X_1 = X_{bp} + w\tilde{e}_g\bar{e}_g(1 - \frac{\tau_{ss}}{2})\mathbb{1}_{\{g<T_r\}} + b\mathbb{1}_{\{g\geq T_r\}} + transfer. \tag{5.2}$$

The first component in (5.2), X_{bp}, represents business profits. The tax rate of the last term in (5.1), τ_{st}, captures taxes other than the nonlinear income tax and is pinned down in equilibrium. Payroll taxes like social security tax are deductible when computing federal taxable income, b represents Social Security benefits, and $transfer$ denotes the lump-sum transfer evenly distributed by the government from the total wealth left behind by the deceased of the model. I strictly set the flat rate of taxes on capital income earned from savings, τ_{sv}, to 15% in the economy $\mathcal{E}^1$. The number falls in the range of capital income tax rates that are commonly adopted in the dynamic tax policy literature.[1] The equilibrium of the model economy $\mathcal{E}^1$ is solved by adjusting τ_{st} to balance the government budget such that government expenditures G (the sum of government purchases G_p and government debt services G_i) is financed by tax revenues collected under the tax schedule $\mathcal{T}^1$.

5.1.1 The flat rate wealth taxation

In the second policy experiment, I attempt to evaluate the welfare impact of an extreme wealth tax scheme, $\mathcal{T}^2$, in comparison with the hybrid tax system, $\mathcal{T}^1$, which is enacted in the baseline economy $\mathcal{E}^1$. Recall that $\mathcal{T}^1$ comprises a proportional capital income tax of 15% and a nonlinear tax scheme on other taxable incomes. The tax reform from $\mathcal{T}^1$ to $\mathcal{T}^2$ executed is to replace the existing flat-rate capital income tax with taxes on wealth (capital stock). The rate of the introduced wealth taxation is set revenue-neutrally in the sense that the tax revenues collected by $\mathcal{T}^2$ equals to the level of government expenditure obtained in the equilibrium of the baseline economy $\mathcal{E}^1$.

[1] In the literature of optimal capital income taxation, authors search for the optimal tax rates on capital income in the range from 0% to 40%; see Diamond and Viard (2008); İmrohoroğlu (1998); Kitao (2008); Nakajima (2010) for example. In Nakajima (2010), he fixes the capital income tax at the rate of 40%. Since the optimal capital income taxation is out of the scope in the current study, for simplicity, I set the flat rate of taxes on returns from savings to 15% for the tax schemes $\mathcal{T}_i^1(X_{bp}, X_{sv}, X_1)$ and $\mathcal{T}_i^3(X_{bp}, X_{sv}, X_3)$.

Holding others unchanged, I set the tax rate of capital income, τ_{sv}, to zero, and levy taxes on wealth at a flat rate of τ_w. In this alternative economy $\mathcal{E}^2$, the tax schedule is defined by

$$\mathcal{T}_i^2(X_{bp}, X_{sv}, X_2) \quad = \quad \tau_w[(a-k)^+ + (1-\delta_h)h + X_2], \tag{5.3}$$

where $X_2 = X_1 + X_{sv}$. The superscript 2 indicates that this tax scheme is implemented in the economy $\mathcal{E}^2$. Note that, relative to the beginning tax scheme in the current policy experiment, $\mathcal{T}^1$, the difference is the consideration of wealth taxation. The corresponding tax base is expanded to encompass housing stock and financial wealth (h and a), in addition to incomes from saving X_{sv} and business profits X_{bp}. The wealth tax rate is calibrated so as to generate the same amount of tax revenues as that amassed in the baseline economy $\mathcal{E}^1$. Therefore, tax revenue remains constant between the equilibrium of the beginning economy $\mathcal{E}^1$ and the alternative economy $\mathcal{E}^2$ in the tax reform from the tax scheme $\mathcal{T}^1$ to $\mathcal{T}^2$.

5.1.2 The progressive wealth taxation

To answer the second main question of this study concerning the welfare effect of the progressive wealth tax scheme proposed by Piketty (2014), I conduct the third policy experiment as devised below. The alternative tax scheme $\mathcal{T}^3$ is an augment of the basic tax scheme implemented in the calibrated model $\mathcal{E}^0$ where only a nonlinear income taxation is in effect:

$$
\begin{aligned}
\mathcal{T}_i^3(X_{bp}, X_{sv}, X_3) &= a_{i,0}\left[X_3 - (X_3^{-a_{i,1}} + a_{i,2})^{-1/a_{i,1}}\right] + \tau_{st} X_3 \\
&\quad + 0.02 \max[W_3 - \$6.5 \text{ million}, 0] \\
&\quad + 0.01 \max[W_3 - \$1.3 \text{ million}, 0] \mathbb{1}_{\{W_3 < \$6.5 \text{ million}\}} \qquad (5.4)
\end{aligned}
$$

where X_3 and W_3 are, respectively, taxable income and net worth in the end of period, each of which are defined by:

$$
\begin{aligned}
X_3 &= X_{bp} + X_{sv} + w\tilde{e}_g \bar{e}_g (1 - \frac{\tau_{ss}}{2}) \mathbb{1}_{\{g < T_r\}} + b \mathbb{1}_{\{g \geq T_r\}} + transfer \qquad (5.5) \\
W_3 &= X_3 + (a - k)^+ + (1 - \delta_h) h. \qquad (5.6)
\end{aligned}
$$

In this policy experiment, the alternative tax base under the nonlinear income tax scheme, X_3, is actually identical to the tax scheme implemented in the baseline economy $\mathcal{E}^1$. Likewise, the definition of the alternative tax base under the basic version of the Piketty-type Piketty (2014) progressive wealth tax scheme, W_3, is equivalent to that in the economy $\mathcal{E}^2$. In other words, the experimental tax policy to be introduced in the current policy experiment is a hybrid of two extreme cases of taxation—a pure capital income tax scheme and a pure wealth tax scheme—up to the same consideration of the nonlinear income tax scheme. To make the outcome of model simulation comparable among policy experiments, the benchmark economy is chosen to be the baseline economy $\mathcal{E}^1$ for all the policy experiments defined so far.

5.2 Measure of social welfare

After solving the stationary equilibrium in the economies $\mathcal{E}^2$ (under $\mathcal{T}^2$, a flat wealth tax) and $\mathcal{E}^3$ (under $\mathcal{T}^3$, a mix of a capital income tax and a progressive wealth tax), I evaluate the implied macro effects of respective tax reforms by comparing the aggregate variables and inequality indices of these two alternative economies with their counterparts in the benchmark economy $\mathcal{E}^1$. The aggregate variables of interest include output, housing stock, financial wealth, and net worth. The key measurement of firm dynamics such as the number of self-employment, employment, productivity, and capital investment are also investigated.

I quantify the welfare losses or gains that result from a tax reform by computing the consumption equivalent variation (CEV). It measures the constant increment in percentage of consumption of every household (technically, every combination of state variables) so that households are indifferent between maintaining the benchmark tax scheme and supporting the alternative tax scheme implied by the tax reform.

The remaining ingredient of my welfare analysis is the social welfare function ranking different tax schemes. The core question that normally arises in a normative analysis of this kind is what kind of welfare criterion I take a stand on. I assume that the government wants to maximize the ex-ante (before talents are realized) expected (with respect to uninsurable shocks) lifetime utility of a model entrant (i.e., a household whose head is 20 years old) into a stationary equilibrium implied under the chosen tax scheme. Central to this welfare is a concern of the policymaker for insurance against idiosyncratic shocks and redistribution among agents of different abilities, as commonly presumed in the literature; see, e.g., Conesa, Kitao, and Krueger (2009). The measurement of the social welfare under the tax scheme j is defined by:

$$W^j = \int \sum_{g=1}^{T} \beta^g \xi_g \, u\left(c_g^j(\mathcal{S}_g), h_g^j(\mathcal{S}_g)\right) d\mu_g, \tag{5.7}$$

where ξ_g denotes the unconditional survival probability of living up to g years. Given the fact that the household is alive at age $g-1$, the conditional probability of surviving through age g is written as ξ_g/ξ_{g-1}. And, $c_g^j(\cdot)$ and $h_g^j(\cdot)$ are the policy functions of consumption of nonhousing goods and housing services, and μ_g is the associated stationary distribution for age group g.

The welfare gains (or losses) after moving from the benchmark economy $\mathcal{E}^i$ to the alternative economy $\mathcal{E}^j$ is measured by the uniform percentage increment in nonhousing consumption goods, $\varepsilon > 0$ (or $\varepsilon < 0$). The quantification of ε is computed implicitly from the following equation:

$$W^j = \int \sum_{g=1}^{T} \beta^g \xi_g \, u\left((1+\varepsilon) c_g^i(\mathcal{S}_g), h_g^i(\mathcal{S}_g)\right) d\mu_g. \tag{5.8}$$

Equation (5.8) equates the social welfare in the alternative economy $\mathcal{E}^j$ (i.e., W^j; the left hand side of the equation) with the adjusted social welfare on basis of the optimal consumption paths in the benchmark economy $\mathcal{E}^i$ such that the consumption of non-housing goods across households is raised by a proportion ε in the benchmark economy $\mathcal{E}^i$ (the right hand side). A negative ε quantifies (5.8) how much the whole households is willing to give up with respect to optimal consumption under the benchmark tax scheme $\mathcal{T}^i$ in order to repeal the alternative tax policy $\mathcal{E}^j$.

5.3 Results

In this section, I report the simulation outcome of each policy experiment defined in Section 5.1. The pairwise comparisons among the tax schemes ($\mathcal{T}^1$, $\mathcal{T}^2$, and $\mathcal{T}^3$), by comparing the implied economic performance and the level of social welfare with one another, are documented. In Subsection 5.3.10, I conduct sensitivity analysis of the calibrated mode when I use alternative parameters that are linked to the entrepreneurial activities and the existence of housing asset, as well as policy experiments under alternative parameterizations.

5.3.1 The proportional wealth tax

Recall that one of the taxes levied in the calibrated model of the US economy, $\mathcal{E}^0$, is a nonlinear income tax that mimics the federal income tax enacted in the US. The calibrated model also consider a flat rate of taxes on household income for balancing the government budget in equilibrium. Furthermore, the baseline economy $\mathcal{E}^1$ accounts for a proportional rate of taxes on the interest earned from savings in addition to the tax scheme implemented in the calibrated economy $\mathcal{E}^0$. The rate of capital income tax is set strictly to 15%. The resulting tax scheme of the baseline economy $\mathcal{E}^1$ is denoted by $\mathcal{T}^1$. The first policy experiment starts with the current subsection 5.3.1.

5.3.2 Macro aggregates

The tax reform analyzed in this subsection is a tax swap from the tax scheme $\mathcal{T}^1$ to the pure wealth tax scheme $\mathcal{T}^2$, which considers only a flat wealth tax and imposes it on every households without any exemptions. For expositional convenience, I denote this tax reform (or exchangeably, policy experiment) from the initial tax scheme $\mathcal{T}^1$ to the alternative tax scheme $\mathcal{T}^2$ by $\mathcal{P}^1$. Table 5.1 lists aggregate variables and inequality indices obtained in the

Table 5.1: Macro aggregates and inequality in $\mathcal{E}^1$ and $\mathcal{E}^2$: Part I.

	Tax policy		
Variable	$\mathcal{T}^1$	$\mathcal{T}^2$	% Change
Prices			
wages	0.5881	0.5830	-0.87%
interest rates	0.0460	0.0488	6.18%
Aggregate statistics			
total output	0.8510	0.8436	-0.87%
corporate sector	0.4308	0.4250	-1.33%
entrepreneurial sector	0.4203	0.4186	-0.40%
housing asset	0.1710	0.1540	-9.90%
financial wealth	0.3267	0.3146	-3.72%
share of business households	0.1081	0.1058	-2.12%

stationary equilibrium of the economies $\mathcal{E}^1$ and $\mathcal{E}^2$, respectively. The equilibrium prices move in diverse directions after the tax reform. The wage rate goes down by 0.87%, while the interest rate increases by 6.18%; see the first section in Table 5.1. The movement of the interest rate reflects the shrinkage of the underlying capital stock. It is a general equilibrium effect of the flat wealth tax. The reason behind is simply that the wealth tax targets not only capital income but also capital stock, which demotivates households to save. It is especially the case when the returns on savings are smaller than the flat wealth tax. The aggregates of household housing stock and financial wealth drop by 9.9% and 3.72%, respectively; see the last two row of the Aggregate statistics section. A secondary effect of the decrease in capital stock is that total output falls off by 0.87%. It is worth noting that the share of capital employed in the entrepreneurial sectors remains roughly 50% across the economies $\mathcal{E}^1$ and $\mathcal{E}^2$, as observed in the data (see Quadrini, 1999).

Table 5.2: Income quintiles in $\mathcal{E}^1$ and $\mathcal{E}^2$.

	Quintiles in income distribution				
	First	Second	Third	Fourth	Fifth
Tax to income (%)					
$\mathcal{T}^1$	0.1142	0.1257	0.1460	0.1662	0.2379
$\mathcal{T}^2$	0.2657	0.2826	0.2759	0.2014	0.1691
% change	132.71	124.89	88.94	21.20	-28.94
Tax to wealth (%)					
$\mathcal{T}^1$	0.0515	0.0556	0.0684	0.1161	0.1952
$\mathcal{T}^2$	0.1366	0.1366	0.1366	0.1366	0.1366
% change	165.34	145.63	99.86	17.70	-30.00
Total wealth					
$\mathcal{T}^1$	0.4403	0.6953	1.1953	1.2392	3.0711
$\mathcal{T}^2$	0.3540	0.6075	1.1053	1.2591	3.1234
% change	-19.60	-12.64	-7.54	1.60	1.70
Fraction of entrepreneurs					
$\mathcal{T}^1$	0.0026	0.0005	0.0178	0.0045	0.0828
$\mathcal{T}^2$	0.0017	0.0005	0.0134	0.0074	0.0828
% change	-33.81	-4.67	-24.69	67.13	0.01

5.3.3 Household statistics

In the Household statistics section of Table 5.1, the fraction of entrepreneurs downsizes by 2.12%. Households appear less likely to enter entrepreneurship than they would in $\mathcal{E}^1$. One possible interpretation is that the general equilibrium effect of this tax reform—the effect which causes the decrease in wages and the increase in the interest rates—makes households with good entrepreneurial talent take more time to overcome financial constraints on entering or staying in entrepreneurship. They either accumulate their business capital slower due to the thinner wage income or face higher costs of external financing because of the rise of the interest rate. This evidence of this interpretation could be found in the presence of business households across income quintiles shown in the bottom row of Table

Table 5.3: Macro aggregates and inequality in $\mathcal{E}^1$ and $\mathcal{E}^2$: Part II.

Variable	Tax policy $\mathcal{T}^1$	Tax policy $\mathcal{T}^2$	% Change
Household statistics			
median income of worker households	0.7929	0.7822	-1.35%
wealth of poor 20% worker households	0.3373	0.3269	-3.08%
Gini indices			
pre-tax income	48.93	50.11	2.41%
post-tax wealth	41.65	46.23	11.00%
consumption	35.58	40.74	14.50%

5.2. It is obvious the lowest-income quintile is hit severely by the tax reform in the dimension of entrepreneurship, since the number of entrepreneurs within the quintile decreases significantly by 33.81%. The loss of entrepreneurs persists across income quintiles except for the fourth and fifth quintiles. Both of these two high-income quintiles experience an increase in the number of business households. In particular, the head counts of the business households in the fourth quintile soars by 67% .

Turning back to household statistics in Table 5.3, the median income in worker households drops by 1.35%. Household wealth facing the poor 20% in the worker household distribution declines by 3.08%. An explanation for this change in median income is that labor income accounts for a large share of earnings in worker households. Due to the fall in wages, the wealth accumulation of worker households under the pure wealth tax scheme $\mathcal{T}^2$ is held back by the tax reform from being at the same speed as in the benchmark economy $\mathcal{E}^1$. The rise in the interest rates raise the rate of returns on savings, but it fails to offset the reduction in household labor income. Thus, the change in median household income turns out to be negative after the tax reform.

5.3.4 Inequality

In the bottom section of Table 5.3, I display the measurements of inequality with respect to three horizons—pre-tax income, post-tax wealth, and consumption. The distribution of consumption turns out to be the least severe among the three dimensions of interest. The Gini index of household pre-tax wealth is the highest among the three indicates. Besides, in Table 5.3 I show that each Gini index considered goes up after the tax reform. The Gini index of consumption rises from 35.58 to 40.74, or by 14.5%. The Gini indices of post-tax wealth also adversely increases by 2.41%. These trends imply that the flat rate wealth taxation worsens the issue of inequality in the benchmark economy.

In Table 5.2, the first section reports the changes in tax burden, measured by the ratio of tax to income, in each income quintile of the economies $\mathcal{E}^1$ and $\mathcal{E}^2$. The first four quintiles face an increase in their tax burden, which ranges from 21.2% up to 132.71%. Conversely, the fifth (the most income-rich) quintile experiences a reduction of tax relative to incomes by 28.94%. The worst situation happens to the first (lowest-income) quintile, whose tax burden surges by more than 130%. Even if we switch the measurement of tax burden to the ratio of tax to wealth, the similarity of shifts in tax burden can be observed. The first quintile's tax burden rises by 165.34%, while the fifth quintile fares even better than when the measure of inequality is the ratio of tax to income.

The shifts in tax burden can also be justified by the changes in tax payment captured by the model-generated age profiles of tax payment. Figures 5.1 and 5.2 show the life cycle patterns of tax payment made by worker and business households. Shaded area marks the difference in the amount of tax payment due to the tax switch. For area shaded in blue, the age groups under the area benefit from the tax reform, while for area shaded in red, the associated age groups are required to pay more tax than they would in the benchmark economy. Figure 5.1 shows that nonbusiness households of age 55 or older—including

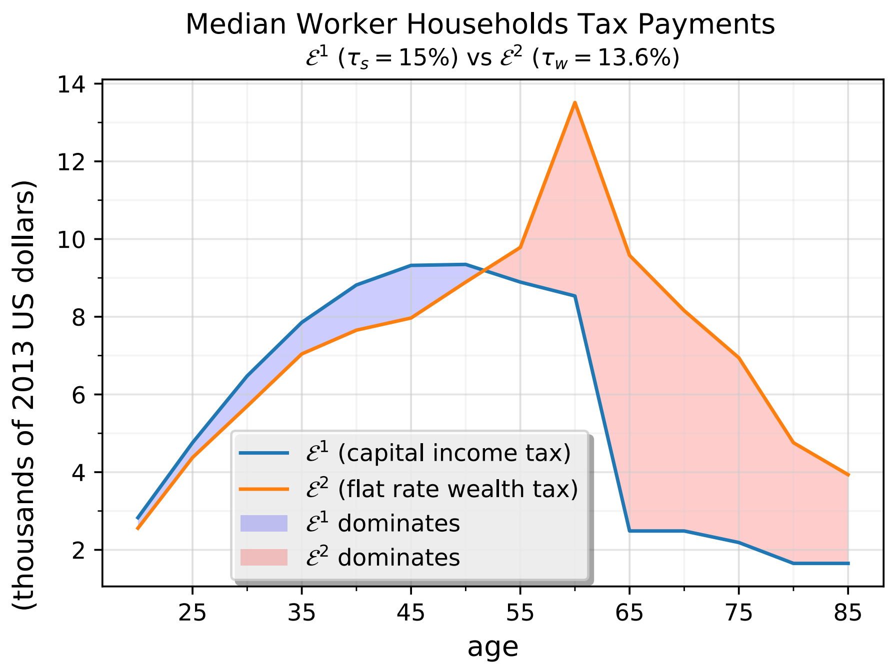

Figure 5.1: Age profiles of tax payment in the median worker households in $\mathcal{E}^1$ and $\mathcal{E}^2$.

senior worker households and households whose head is retired—experience a tax payment hike.

Why senior worker households and the households whose head is retired (the latter is grouped into the worker households in the model simulation) are required to make more wealth tax payment than others? It is because senior households have more housing asset than financial wealth in their asset portfolio. Such a specific asset composition results from worker households' preference in dissaving financial wealth rather than housing asset in the later stage of lifetime. The mechanism behind this phenomenon is that in the model economy adjusting the quantity of housing asset is costly, while the model environment doesn't assume any costs for trading financial wealth. This model-generated life cycle patterns of wealth holdings in worker households matches the findings in the empirical exercise: Regardless of how old a worker household head is, the amount of the household's housing

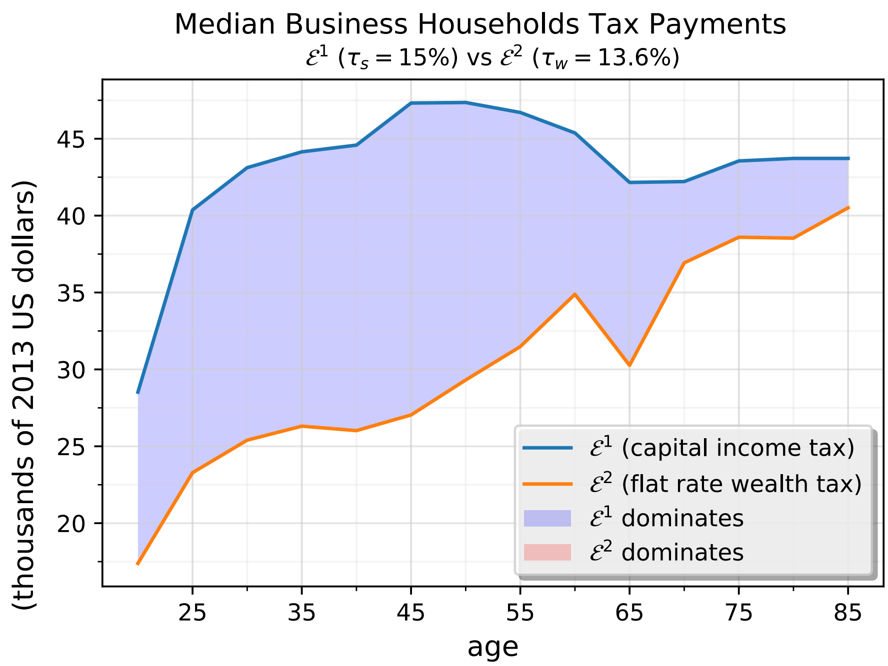

Figure 5.2: Age profiles of tax payment in the median business households in $\mathcal{E}^1$ and $\mathcal{E}^2$.

asset holdings dominates that for financial wealth holdings. The share of housing asset thus even increases in their retirement, due to their dissaving preference. Since the housing asset holdings in worker households would otherwise not be taxable under the initial tax scheme $\mathcal{T}^1$, the percentage change in tax payment for these low-income households are substantially larger after the tax reform.

Due to their dissaving preference, households whose heads are retired or senior workers need to pay more taxes under the alternative tax scheme $\mathcal{T}^2$. Since the proposed life cycle model by construction features that the retired and senior worker households constitute the majority of the low-income households, the direction of shifts in tax burden is from the high-income groups to the low-income groups in the simulation of the current policy experiment.

The other question pertaining to the shifts of tax burden is why high-income households are better off even under an extreme wealth tax scheme that is intended to be in favor of household with less wealth or low income. First of all, one feature of the proposed life cycle model is that business households dominate in the high-income groups. It is because households with entrepreneurial talent have the chance to grasp higher returns from risky business investment than earn the risk-free returns to savings or exchange their labor efficiency endowment for wages. Therefore, business households make up the majority of high-income quintiles. Furthermore, business households make less tax payment in the alternative economy $\mathcal{E}^2$ (see Figure 5.2). Why their tax payment drops? The reason is that the amount of tax revenue to be collected is predetermined (recall that it is fixed and equals to the amount of government spending estimated in the calibrated economy, $\mathcal{E}^0$) and, in the meantime, that worker households are required to pay more taxes due to their saving preference. As a result, business households end up with making less contribution to the total tax revenue collected in the alternative economy $\mathcal{E}^2$.

The alternative economy is poorer in terms of capital stock, less efficient with respect to production, and observes more inequality in consumption, income and wealth among households. Although the analysis of inequality stated above mostly focuses on the data of the consumption distribution, the same interpretation should be readily applied to the other two dimensions in pre-tax income and post-tax wealth.

5.3.5 The progressive wealth tax

In this subsection, I report the outcome of the policy experiment $\mathcal{P}^2$ in evaluating the macro effects of the Piketty-type (2014) progressive wealth tax defined in Subsection 5.1.2. Recall that the tax scheme $\mathcal{T}^3$ is a hybrid of the nonlinear income tax scheme $\mathcal{T}^0$, the flat rate of capital income tax considered in $\mathcal{T}^1$, and the basic version of the progressive wealth tax scheme proposed by Piketty (2014). The benchmark economy in the current policy experiment $\mathcal{P}^2$ remains the baseline economy $\mathcal{E}^1$. A flat rate of taxes on household taxable incomes is introduced into the alternative economy $\mathcal{E}^3$ to balance the government budget constraint in stationary equilibrium as I do in the solution of the stationary equilibrium for the economies $\mathcal{E}^0$ and $\mathcal{E}^1$.[2]

Table 5.4: Macro aggregates and inequality in $\mathcal{E}^1$ and $\mathcal{E}^3$: Part I.

	Tax policy		
Variable	$\mathcal{T}^1$	$\mathcal{T}^3$	% Change
Prices			
wages	0.5881	0.5837	-0.75%
interest rates	0.0460	0.0484	5.27%
Aggregate statistics			
total output	0.8510	0.8447	-0.75%
corporate sector	0.4308	0.4259	-1.14%
entrepreneurial sector	0.4203	0.4188	-0.34%
housing asset	0.1710	0.1704	-0.33%
financial wealth	0.3267	0.3163	-3.18%

5.3.6 Macro aggregates

In Table 5.4, I report the changes in macro aggregates and the Gini indices in response to the tax reform from $\mathcal{T}^1$ to $\mathcal{T}^3$. The equilibrium prices move in diverse directions as they do in the policy experiment with a flat wealth tax. The wage rate goes down by 0.75%, which is smaller than 0.87%, the percentage change of the wage rate in the policy experiment $\mathcal{P}^1$. The interest rates rise by 5.27%, which is more moderate than its counterpart in $\mathcal{P}^1$ of 6.18%. Besides, the issue of inefficiency in production and slowdown in wealth

[2]This strategy is not used in the solution of the economy $\mathcal{E}^2$ in which case the endogenously-determined flat wealth tax rate is pinned down by balancing the government budget condition in stationary equilibrium. So the solution of $\mathcal{E}^2$ needs not to take the flat income tax into consideration for the purpose of balancing the government budget.

accumulation observed in $\mathcal{P}^1$ is relatively milder in the current case $\mathcal{P}^2$. Total output decreases by 0.75%, as opposed to its counterpart in $\mathcal{P}^1$ of 0.87%. Aggregate financial wealth falls only by 3.18%, which is slightly improved relative to the corresponding percentage change, 3.72%, observed in $\mathcal{P}^1$. It is worth noting that the improvement on the decrease of housing asset holdings is stronger than previous aggregate variables. In the current policy experiment, the reduction of housing stock after the tax reform is only 0.33%, while the shrinkage of housing stock is nearly as much as 10% in $\mathcal{P}^1$. Generally, the progressive tax scheme $\mathcal{T}^3$ outperforms the flat wealth tax scheme $\mathcal{T}^2$ but is still inferior to the flat capital income tax $\mathcal{T}^1$, in terms of total output and capital stock.

Table 5.5: Macro aggregates and inequality in $\mathcal{E}^1$ and $\mathcal{E}^3$: Part II.

	Tax policy		
Variable	$\mathcal{T}^1$	$\mathcal{T}^3$	% Change
Household statistics			
share of business households	0.1081	0.1062	-1.78%
median income of worker households	0.7929	0.7833	-1.21%
wealth of poor 20% worker households	0.3373	0.3348	-0.75%
Gini indices			
pre-tax income	48.93	48.88	-0.10%
post-tax income	46.23	46.02	-0.45%
post-tax wealth	41.65	41.58	-0.17%
consumption	35.58	35.6	0.06%

5.3.7 Firm dynamics and household-level statistics

Turing to the statistics at the household level, in Table 5.5, I show that the size of the business households population shrinks after the tax reform in $\mathcal{P}^2$ by 1.78%. In addition, the median income of worker households declines by 1.21%, and the wealth holdings of the poor 20% worker households decrease by 0.75%.

The effect of the progressive wealth tax reform is comparatively milder on firm dynamics, household wealth holdings and inequality as compared with the flat wealth tax reform in $\mathcal{P}^1$. There are more entrepreneurs in the alternative economy $\mathcal{E}^3$ after the tax reform in the current experiment $\mathcal{P}^2$. The fraction of business households in the population only drops by 1.78%, relative to 2.12% in $\mathcal{E}^2$ of the policy experiment $\mathcal{P}^1$. The median income of worker households goes down by 1.21%, a negative change which is relatively moderate as opposed to the falls of worker households' median income of 1.35% in $\mathcal{P}^1$. It is noteworthy that the wealth of the poor 20% worker households in $\mathcal{E}^3$ are affected by the tax reform much less than they are in $\mathcal{E}^2$. The decrease in wealth holdings of the poor 20% of the worker household is less than 1% relative to the larger negative percentage change of 3.08% observed in $\mathcal{E}^2$.

The effects of the progressive wealth tax reform are mixed on the measurements of inequality with respect to the direction of the changes. In Table 5.5, the Gini indices of the distributions of pre-tax income and post-tax wealth are improved in the sense that the index of pre-tax income goes down by 0.1% and that of post-tax wealth declines but in a slightly stronger manner by 0.75%. On the contrary, the tax reform worsens the inequality in consumption to some degree. The Gini index of household consumption goes down by less than 0.1%. When compared with their counterpart in $\mathcal{P}^1$, the changes in the Gini indices of interest in $\mathcal{P}^2$ move deeper toward the area of less inequality. Overall, to the extent that the inequality in the distribution of household (pre-tax) income and (post-tax) wealth are what the policymakers are concerned about and that the moderate rise in consumption inequality is tolerable by inequality-adverse households, the progressive wealth tax scheme implemented in $\mathcal{E}^3$ is a better tax scheme in terms of inequality alleviation relative to the capital income tax scheme $\mathcal{E}^1$ and the flat wealth tax scheme $\mathcal{E}^2$.

Table 5.6: Income quintiles in $\mathcal{E}^1$ and $\mathcal{E}^3$.

	Quintiles in income distribution				
	First	Second	Third	Fourth	Fifth
Tax to income (%)					
$\mathcal{E}^1$	0.1142	0.1257	0.1460	0.1662	0.2379
$\mathcal{E}^3$	0.1094	0.1238	0.1477	0.1670	0.2391
% change	-4.18	-1.47	1.14	0.49	0.50
Tax to wealth (%)					
$\mathcal{E}^1$	0.0515	0.0556	0.0684	0.1161	0.1952
$\mathcal{E}^3$	0.0576	0.0452	0.0817	0.1194	0.1956
% change	11.90	-18.76	19.51	2.87	0.20
Total wealth					
$\mathcal{E}^1$	0.4403	0.6955	1.1949	1.2391	3.0706
$\mathcal{E}^3$	0.3845	0.8857	1.0684	1.2010	3.0408
% change	-12.67	27.35	-10.58	-3.07	-0.97
Fraction of entrepreneurs					
$\mathcal{E}^1$	0.0026	0.0005	0.0177	0.0044	0.0828
$\mathcal{E}^3$	0.0016	0.0002	0.0160	0.0059	0.0825
% change	-40.13	-54.08	-9.75	32.62	-0.39

5.3.8 Shifts in tax burden across income quintiles

In Table 5.6, I display the shifts in tax burden as well as the changes in wealth holdings across income groups in $\mathcal{P}^2$. The first section is pertaining to household tax burden measured by the ratio of tax to income. The changes in tax burden range from -4.18% for the lowest-income quintile to 0.5% for the highest-income quintile. There exists a trend of changes in tax burden, which features a monotonically increasing movement starting from the first (lowest-income) quintile all the way to the fifth (highest-income) quintile. This observation shows that the adverse shifts in tax burden in $\mathcal{P}^1$, where the low-income households pay more taxes relative to their income after the flat wealth tax reform. This shift is absent under the progressive tax scheme $\mathcal{T}^3$.

If we switch the measurement of inequality to the ratio of tax to wealth, the changes are mixed among the income quintiles, but, by and large, they move in the favorable direction relative to the tax reform in $\mathcal{P}^1$ in the sense that all of the quintiles have a lower tax burden in $\mathcal{P}^2$ relative to their counterparts in $\mathcal{P}^1$. The only exception is the fifth quintile whose tax burden measured by the ratio of tax to wealth is about 0.14% in $\mathcal{E}^2$, but roughly 0.2% in the current alternative economy $\mathcal{E}^3$. This observation reflects the fact that the progressive wealth tax scheme targets the top rich households and let households with less wealth be exempted from the taxation.

5.3.9 Welfare effects of $\mathcal{T}^2$ and $\mathcal{T}^3$

In this subsection, I compare the welfare effects of the proportional wealth tax reform $\mathcal{P}^1$ with those of the progressive wealth tax reform $\mathcal{P}^2$. The measurement of the social welfare is the ex-ante expected lifetime utility of a new-born household at the beginning of period one in the stationary equilibrium of an economy of interest.

In Table 5.7, I report changes in social welfare measured in consumption equivalent terms. I tabulate the CEV of households grouped by age and occupation for the policy experiments $\mathcal{P}^1$ and $\mathcal{P}^2$ under the first two columns. Based on the sign and absolute value of CEV, we can quantitatively understand to which degree a group of households like or dislike a tax reform. For example, in the flat wealth tax reform $\mathcal{P}^1$, the CEV of the first two youngest age groups are -7.3% and -8.4%, respectively. In this case, the negative sign of the CEV indicates that the two groups of households are willing to sacrifice a fraction of their consumption in the benchmark economy $\mathcal{E}^1$ in exchange for being rid of the flat wealth taxation $\mathcal{T}^2$. The absolute value of CEV reveals to which degree the households favor or dislike a tax reform. For example, the youngest age group is willing to sacrifice 7.3% of their consumption in the benchmark economy $\mathcal{E}^1$ to reject the implementation of

Table 5.7: Consumption equivalent variations across age and occupational groups.

	% change		% change	
Class	$\mathcal{P}^1$	$\mathcal{P}^2$	$\widetilde{\mathcal{P}^1}$	$\widetilde{\mathcal{P}^2}$
Age groups				
20-25	-7.3	-3.7	-10.7	0.2
25-30	-8.4	-9.1	-6.2	0.0
30-35	-2.1	0.2	-4.2	0.1
35-40	-1.4	-2.7	-6.0	0.1
40-45	-0.1	-1.1	-5.1	0.1
45-50	-1.0	2.5	-0.9	0.1
50-55	-0.8	0.9	-1.5	-0.1
55-60	-3.4	-0.9	-4.9	-0.2
60-65	-7.1	-0.6	-8.1	-0.6
65-70	-12.3	0.8	-13.0	-0.7
70-75	-17.0	2.3	-19.2	-0.4
75-80	-22.5	2.4	-26.7	-0.1
80-85	-26.9	-1.4	-30.5	0.7
85-90	-36.2	-2.0	-33.0	1.2
Household groups				
whole	-8.99	-2.04	-11.16	0.03
worker	-9.96	-2.26	-12.08	0.02
business	7.97	1.54	4.66	0.20

Note: $\mathcal{P}^1$ is the tax reform from the initial economy $\mathcal{E}^1$ to the alternative economy $\mathcal{E}^2$. $\mathcal{P}^2$ is the tax reform from the initial economy $\mathcal{E}^1$ to the alternative economy $\mathcal{E}^3$. For an economy $\mathcal{E}^i$, the designated tax scheme is denoted by $\mathcal{T}^i$. In the first two column are the changes in CEV in the tax reforms $\mathcal{P}^1$ (1st column) and $\mathcal{P}^2$ (2nd column). The third and fourth columns are left for the same tax reform as in $\mathcal{P}^1$ and $\mathcal{P}^2$, respectively, except the absence of housing from the model environment. I denote these two tax reforms with a tilde on top of the tax reform with which they are associated. For example, $\widetilde{\mathcal{P}^1}$ has the same setup as $\mathcal{P}^1$ except the latter accounting for housing asset.

the flat wealth tax, while those of ages 40 to 45 are willing to give up merely 0.1% of their consumption in $\mathcal{E}^1$ in exchange for the repeal of the flat wealth taxation.

Looking at the percentage changes in CEV under the first column, we can find a clear pattern shown in the age profile of CEV in the first section under the $\mathcal{P}^1$ column. The pattern can be roughly divided into three distinct but adjoining periods over the life cycle. In the first period, which is related to young households of 20 to 45 years old, the age profile of CEV is trending upward until reaching the maximum at the level of -0.1%, observed in the age group of 40 to 45 years old. An explanation about this trend is that, in the model economy, households tend to be in their poorest period of lifetime when they are young. For this subgroup of the population, they save more in housing asset than financial wealth for the purpose of building up their collateralizable housing stock to overcome their financial constraint on business entry. As they are older, they increase their financial wealth holdings. It is a feature of two-asset life cycle models as demonstrated in Yang (2009), which finds that borrowing constraints are needed to explain the accumulation of housing early. Therefore, the younger households are in the model, the more losses in welfare they have after the flat wealth tax reform because of their preference for holding housing asset.

The second stage is associated with households of 45 to 55 years old. Their CEV is around -0.9%. After this stage, the age profile of CEV is trending downward. The reason is that people in the later stage of life, particularly people in the retirement, dissave financial assets to smooth their consumption. Housing asset holdings remain steady throughout the later stage of lifetime as shown in the empirical exercise of this study. One of potential factors for explaining about the slow downsizing of housing later in life is high transaction costs of housing asset (see Yang, 2009). As a consequence, the proportion of housing asset in asset portfolio rises, causing households in the retirement age to have larger and larger welfare losses in the flat wealth tax reform $\mathcal{P}^1$ as they age.

Note that the rationale I made above for explaining the nonlinear life cycle pattern of welfare gains or losses for the whole population simply relies on the features of the life cycle pattern of wealth holdings found in worker households, which are just a subgroup of the whole population. This simplification is justified by the fact that worker households account for more than 80% of the population. The dominance of worker households makes them representative of the population of households. Besides, worker households form the key group that governs the outcome of the policy experiment when the welfare is weighted by the presence of each subgroup in the population. And it is the case in the current policy experiment. In Table 5.7, I show that even though the group of business households experience huge gains in welfare by 7.97%, the economy as a whole faces losses in welfare by 8.99%. This weighted average is more of leaning toward the losses in welfare of -9.96% experienced by the majority of the population of worker households.

Relative to $\mathcal{P}^1$, the public sentiment in terms of CEV toward the progressive wealth tax reform are not only mixed but also weaker across age groups (see the second column). The largest sacrifice people are willing to make for deterring the enactment of the progressive wealth taxation in $\mathcal{P}^2$ is a reduction by 9.1% in their consumption in the benchmark economy $\mathcal{E}^1$ in comparison with the maximum losses in welfare by 36.2% in the most senior age group in $\mathcal{P}^1$. There exist six age groups that fare better after the progressive wealth tax reform $\mathcal{P}^2$. For example, the age group of 30 to 35 years old experiences the least welfare gains of 0.2%, while age groups of 45 to 50 and 70 to 80 years old have welfare gains in the neighborhood of 2.5%. Conversely, households face losses in welfare universally across all of the age groups after the proportional wealth tax reform.

As for the impacts on welfare across occupation groups in $\mathcal{P}^2$, the economy has less losses in welfare in the progressive tax reform than it would in the flat wealth tax reform. Worker households are not beneficiaries like business households in the progressive tax reform. However, worker households find the progressive wealth tax reform in $\mathcal{P}^2$ less unpleasant in terms of CEV in comparison with how they feel in the proportional wealth tax reform. Similarly, business households are less in favor of the progressive wealth tax reform as opposed to their enthusiasm implied by the absolute value of their positive CEV in the proportional wealth tax reform.

5.3.10 Models without housing or entrepreneurs

I create two duplicates of the calibrated model of the US economy. In each of these duplicates, I remove one of the key elements from the original model environment and then compute the implied wealth distribution in stationary equilibrium. In one duplicate model, I remove the housing asset completely so that the resulting model degenerates to a standard one-asset entrepreneurial model as proposed by Quadrini (2000).

In the other duplicate model, I aim at investigating the importance of stochastic returns on business investments in the proposed two-asset life cycle model to generate the a fat-tailed wealth distribution. Technically, I keep the role of entrepreneurs in the model environment but let the mean of the business shocks be only a small fraction of its counterpart in the calibrated model. By doing so, I create an environment where being a wage earner is a more rewarding occupational decision, and thus suppress the function of entrepreneurship in the resulting model. Figures 5.3 and 5.4 graphically demonstrate the performance of the proposed model in replicating the fat upper tail of wealth distribution observed in the data.

The vertical axis represents the fraction of the households with a specific level of wealth. The horizontal axis represents the levels of wealth in units of thousands of 2013 dollars. The blue histogram displays the real U.S. household wealth distribution based on the SCF in 2010. The fraction of rich households decreases slowly. If we look at the upper

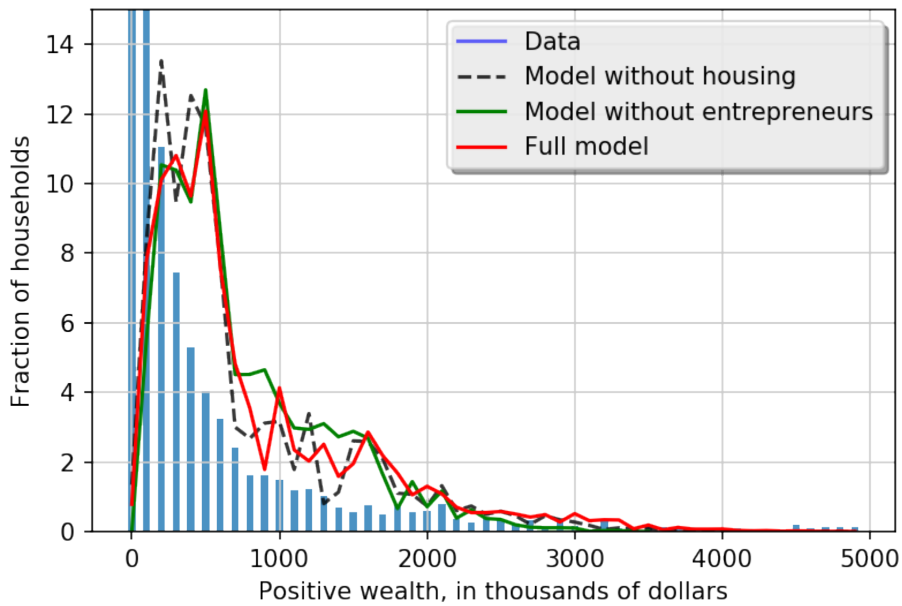

Figure 5.3: Fat-tailed wealth distribution.

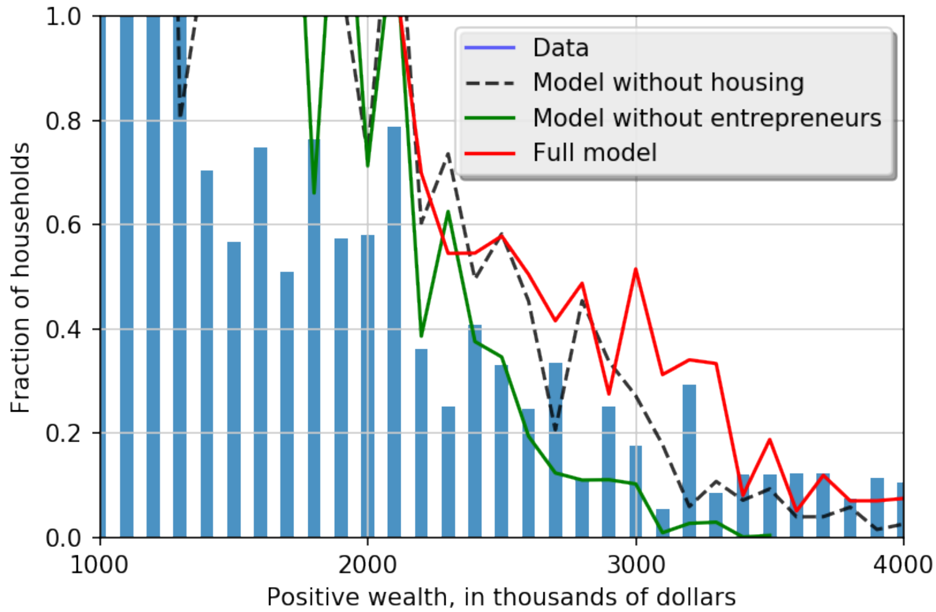

Figure 5.4: Data and model with and without housing and idiosyncratic business shocks.

part of horizontal axis around the wealth levels between \$4 million and \$5 million, it is apparent that there still exists noticeable rich groups clustered in the interval.[3]

To evaluate the performance of the proposed model and its duplicates in approximating the fat-tailed wealth distribution, in Figure 5.4 I zoom in on the wealth interval between \$1 million and \$4 million to identify the subtle performance in matching the data among the three models. I find that the model with an unattractive mean of idiosyncratic business shocks (the line colored in dark green) disappears (i.e., it ends up with touching the axis and never bouncing back afterward) first approximately at the wealth level of \$3.5 million. It is followed by the model without housing asset (the one marked by a black dashed line) begins to lose its pace with the trend made by the calibrated model (the line colored in red) and trending in a weaker manner in the sense that it cannot fully capture the solid existence of rich groups represented by the blue histogram. The result suggests that the shocks to business profits and the role of collateralizable housing asset are indispensable model factors for modeling the thick tail of the empirical wealth distribution.

In Table 5.8, I report the performance of the proposed life cycle model by comparing the outcome of the policy experiment $\mathcal{P}^1$ conducted in the baseline model with that of the same policy experiments conducted in a duplicate model instead. The baseline model is fully equipped with model elements defined in Chapter 4 and the duplicate model has every model factor considered in the baseline model with the exception of one key model element. To make the simulation outcome of both the models comparable, I make the parameter setting in the duplicate model the same as it is in the baseline model.[4]

[3] I truncate household with wealth worthy of more than \$5 million since they are beyond the limits of figures intended to be shown in the text.

[4] Recall that I distinguish variables of the duplicate economy from the baseline model by putting a tilde on top of the notation used in the full model. For example, the policy experiment $\widetilde{\mathcal{P}^1}$ evaluates the effect of the tax reform from the initial tax scheme $\mathcal{T}^1$ to the alternative economy $\mathcal{T}^2$ with the duplicate model with the removal of housing asset. The corresponding initial and alternative economies are, $\widetilde{\mathcal{E}^1}$ and $\widetilde{\mathcal{E}^2}$, respectively.

Table 5.8: Macro aggregates and inequality in $\widetilde{\mathcal{E}^1}$ and $\widetilde{\mathcal{E}^2}$.

	Tax policy		
	$\mathcal{T}^1$	$\mathcal{T}^2$	% Change
Prices			
wages	0.6036	0.5942	-1.56%
interest rates	0.0379	0.0427	12.61%
Aggregate statistics			
total output	0.8634	0.8529	-1.21%
corporate sector	0.4966	0.4697	-5.42%
entrepreneurial sector	0.3668	0.3832	4.49%
housing asset	-	-	-
financial wealth	0.3843	0.3529	-8.17%
Household statistics			
share of business households	0.0992	0.1005	1.35%
median income of worker households	0.8083	0.7862	-2.74%
wealth of poor 20% worker households	0.3370	0.3220	-4.46%
Gini indices			
pre-tax income	49.78	50.92	2.29%
post-tax wealth	42.57	47.17	10.81%
consumption	36.41	41.67	14.45%

Note: The current tax reform (or equivalently, policy experiment) from $\mathcal{T}^1$ to $\mathcal{T}^2$ is denoted by $\widetilde{\mathcal{P}^1}$. The corresponding initial economy is denoted by $\widetilde{\mathcal{E}^1}$ and the alternative economy by $\widetilde{\mathcal{E}^2}$.

The macro aggregates and inequality indices for the policy experiments $\widetilde{\mathcal{P}^1}$ produced by the duplicate model where housing asset is not included. By contrasting the results of prediction between the two tables, I find that the percentage change in prices and aggregate statistics are generally inflated in the duplicate model. For example, the percentage change in the interest rates is 12.61% in the flat wealth tax reform conducted with the duplicate model (see Table 5.8), while its counterpart in the baseline model takes the value of 6.18% in the flat wealth tax reform (see Table 5.1).

The change in the share of business households in the duplicate model takes a different sign than its counterpart in the baseline model. The Gini indices either before or after the tax reform are boosted but the resulting percentage changes caused by the tax reform are all smaller than their counterparts in the baseline model. For example, the Gini index of the post-tax wealth is 42.57 in the initial economy of the tax reform and turns to be 47.17 after the tax reform (see Table 5.8). Both the figures are higher than their counterparts generated by the baseline model, which are 41.65 and 46.23, respectively (see Table 5.3). The corresponding percentage change of the Gini for the post-tax wealth is smaller in the duplicate model than in the baseline model. These observations suggest that the use of a full model with housing asset may generate a totally different prediction than that made by models with the removal of the housing asset. To the extent that models with richer environment setting is more likely to provide predictions in line with the reality, a full model with housing asset could be more favorable than a deficient one.

In the subsequent analysis, I contrast the outcome of policy experiment $\mathcal{P}^2$ between the baseline model and the one-asset duplicate model. The percentage changes in prices and aggregate statistics are mostly mollified in the duplicate model, although the absolute values of the associated variables are actually higher than their counterparts in the baseline model (see Table 5.9 for the outcome of the duplicate model). The financial wealth holdings, for example, drop by 3.18% in the baseline model but fall only two-thirds as much or by 1.99% in the duplicate model. The absolute levels of pre- and post-tax reform financial wealth holdings are respectively 0.3843 and 0.3766. Both of them are higher than their counterparts of 0.3267 and 0.3163 in the baseline model (see Table 5.4 for the baseline model's results).

Turning back to Table 5.7, I find obvious differentials between the baseline and duplicate models in the degrees to which households like or dislike a tax reform. For worker

Table 5.9: Macro aggregates and inequality in $\widetilde{\mathcal{E}^1}$ and $\widetilde{\mathcal{E}^3}$.

	Tax policy		
	$\mathcal{T}^1$	$\mathcal{T}^3$	% Change
Prices			
wages	0.6036	0.6006	-0.50%
interest rates	0.0379	0.0394	3.96%
Aggregate statistics			
total output	0.8634	0.8606	-0.33%
corporate sector	0.4966	0.4902	-1.29%
entrepreneurial sector	0.3668	0.3703	0.98%
housing asset	-	-	0.00%
financial wealth	0.3843	0.3766	-1.99%
Household statistics			
share of business households	0.0992	0.0992	-0.01%
median income of worker households	0.8083	0.8069	-0.18%
wealth of poor 20% worker households	0.3370	0.3357	-0.37%
Gini indices			
pre-tax income	49.78	49.74	-0.08%
post-tax wealth	42.57	42.19	-0.89%
consumption	36.41	36.42	0.03%

Note: The current tax reform (or equivalently, policy experiment) from $\mathcal{T}^1$ to $\mathcal{T}^3$ is denoted by $\widetilde{\mathcal{P}^2}$. The corresponding initial economy is denoted by $\widetilde{\mathcal{E}^1}$ and the alternative economy by $\widetilde{\mathcal{E}^3}$.

households (or the whole population), the negative welfare impacts of the proportional wealth tax reform $\widetilde{\mathcal{P}^1}$ conducted in the duplicate (one-asset) model are generally larger than that of the same tax reform (under a different notation, $\mathcal{P}^1$) conducted in the baseline (two-asset) model. In contrast, business households are less well off after the flat wealth tax reform described in the duplicate model than they would during the same tax reform simulated by the baseline model. For example, worker households in the duplicate model face larger losses in welfare by 12.08% than 9.96% observed in the simulation outcome produced by the baseline model (see the row titled "worker" under the first and third columns). In comparison, for the flat wealth tax, business households experience fewer welfare gains by only 4.66% in the duplicate model than 7.97% in the baseline model.

In addition to the inconsistency in the extent of changes in CEV after the flat wealth tax reform, inconsistency in the direction of changes is observed after the progressive wealth tax reform between the baseline and duplicate models. For example, worker households suffer losses in welfare by 2.26%, which is suggestive of their dissatisfaction about the introduction of the progressive wealth tax scheme. Conversely, they turn to be beneficiaries in the progressive wealth tax reform in the duplicate model because they receive gains in welfare by 0.02%. Due to the fact that the CEV on the aggregate level is a weighted average by the size of subpopulations and that worker households constitute the biggest subgroup of the whole population, the economy is worse off after the progressive wealth tax reform in the baseline model (see the row titled by "whole" under the second column), but is obviously better off in the duplicate model (see the same row under the fourth columns).

The analysis in this subsection suggests that the concerns about the tradeoff between the model richness and the computational complexity is not trivial in the quantitative literature. In the current case, a deficient model with the removal of housing may reverse the conclusion made with a richer model. To the extent that a richer model is equipped with higher degree of modeling freedom to approach the reality better, the use of a deficient model in exchange for the reduction in computational complexity may be at the cost of an incorrect policy suggestion.

Chapter 6

Summary and Conclusions

In this study, I investigate three central questions. Are the life-cycle saving behaviors of entrepreneurial households and wage earner households different? Can life-cycle patterns of wealth holdings in business households be produced by a life-cycle entrepreneurial model? Is wealth taxation a preferred tax policy when compared to capital income taxation?

First, I assess the life-cycle wealth holdings of business oriented (entrepreneurial households) in contrast to that of wage earning (non-entrepreneurial households). To do so, I statistically characterize the life-cycle wealth holding patterns of households particularly by occupational category, based on the pseudo panel data set compiled from the cross-sectional data of the Survey of Consumer Finances. I conclude that the pattern of wealth holding over the life cycle in entrepreneurial households are distinct from that in non-entrepreneurial households. In the median wage earner household, the age profile of financial asset holding is S-shaped and that of housing stock is hump-shaped but exhibiting a flattening out pattern in the second half of lifetime. In comparison, regardless of whether the asset type is housing or financial wealth, asset holding in the median business household grows steadily over the life cycle. The lifetime maximum of housing stock held by the non-entrepreneurial households is at most half as much as that held by the entrepreneurial households. The maximum of non-housing assets possessed by non-entrepreneurial households is only one thirtieth as much as that (including business equity) by entrepreneurial households.

To help explain this pattern of asset holding over the life cycle of households, I develop a quantitative and realistically calibrated dynamic general-equilibrium model of optimal housing and financial wealth holding decisions for finitely lived households. Households are heterogeneous in multiple dimensions including occupational status and entrepreneurial ability. Households face several market frictions including the absence of insurance markets to ensure against shocks to labor- and business-income. I fit the model to the U.S. data and show that it replicates the empirical life-cycle patterns of wealth holding for the U.S. households in the two occupation subgroups of the population.[1]

The flattening out pattern of housing assets is likely due to friction in trading houses. The high transaction costs of housing trade dis-incentivizes senior non-entrepreneurial households from decreasing their housing stock as fast as their financial wealth holding. On the contrary, because of the existence of borrowing constraints and the role of housing as security, young non-entrepreneurial households—who start with only a handful of wealth endowment—borrow as much as possible to buy houses for the purpose of consumption as well as making collateral loans for running businesses to earn higher returns on capital.

This study is not the first that recognizes the features of the life-cycle pattern of wealth holdings for average U.S. households in the data and replicates these features with a quantitative model (See Fernandez-Villaverde and Krueger, 2011 and Yang, 2009 for similar findings). However, this study is the first to documents the age profile of wealth holdings

[1]The only exception is that the simulated life-cycle financial asset holding of non-entrepreneurial households doesn't follow as closely the pattern observed in the data.

for the median entrepreneurial household. Further, it pioneers the reproduction of these features with the calibrated model of the U.S. economy. In the empirical exercise, I find that there exists sustained growth of housing stock and financial wealth holding throughout the lifetime of entrepreneurial households. The intersection of the age profiles of housing asset and financial wealth holdings takes place much earlier in the life of entrepreneurial households as opposed to the case for non-entrepreneurial households. The borrowing for building up the housing stock early in life, as found in the age profile of housing asset holding of non-entrepreneurial households, is not seen in the case of entrepreneurial households. Although entrepreneurial households are subject to the same market frictions like borrowing constraints, the higher rate of returns on business investment help entrepreneurs accumulates wealth fast enough for themselves to be free earlier in life from the reliance on collateral borrowing for smoothing consumption or the last resort to catch investment opportunities. This interpretation may be indirectly justified by the empirical finding in this study that entrepreneurs have less outstanding debts as they age. Similarly, the transaction costs of adjusting the quantity of housing stock is dwarfed by the benefits derived from the growth in the size of asset portfolio propelled by the higher rate of returns on business investment. As a result, the flattening out pattern of housing asset holding that occurs in the later stage of life is not observed in entrepreneurial households.

To answer the third central question about whether wealth taxation is a favorable tax policy as opposed to capital income taxation, I use a realistically calibrated version of the proposed model to examine the welfare and distributional effects of the progressive wealth tax scheme proposed by Thomas Piketty (2014). I conclude that in terms of efficiency in production, the proportional capital income tax scheme, $\mathcal{T}^1$, gives rise to the highest total output among the three tax schemes, $\mathcal{T}^1$, $\mathcal{T}^2$, and $\mathcal{T}^3$. Conversely, in terms of distributional effect measured by shifts in tax burden, the progressive wealth tax scheme, $\mathcal{T}^3$, outperforms the other two tax scheme, $\mathcal{T}^1$ and $\mathcal{T}^2$. It shifts the tax burden from low-income to high-income households. However, the low-income households are worse off because the tax reform induces unfavorable changes in equilibrium prices as well as the surge in tax payments due to their unique preference in asset composition. Wage earning households face losses in labor income, which retard their wealth accumulation, causing them to miss opportunities to enter entrepreneurship due to the lack of business capital. In comparison, entrepreneurial households, especially those who are not financially constrained or borrow against collateralizable housing asset, benefit from cheaper rental prices of labor input and receive higher business income than they would otherwise.

The progressive wealth tax does not widen the income and savings gap between entrepreneurial and non-entrepreneurial households. The Gini indices in the three dimensions of interest all decrease slightly except for the Gini index of consumption. Despite the positive, but almost indiscernible, effects on reducing the Gini indices of pre-tax income and post-tax wealth, the tax reform is not likely to be favored by the majority of the population because of the prevailing welfare costs for the non-entrepreneurial households measured in consumption equivalent terms.

The benchmark economy implements a 15% flat-rate capital income tax. The policy suggestion may vary because of the change in government spending resulting from a different rate of the capital income tax in the benchmark economy. A broader inspection with a range of rates of capital income taxes other than 15% about the impacts of reestablishing fiscal balance after a tax reform would be interesting and is left for future research.

It should be noted that the calibrated model of the U.S. economy has not been subjected to any sensitivity analysis. An extension of the current work is to test the robustness of the model by introducing reasonable disturbances into the calibrated model's parameter setting.

It should be also noted that there might be features of reality that could provide additional reasons to support the enactment of a progressive wealth tax scheme. For example, my model only considers accidental bequests, in which case the government is assumed to levy on the inheritance from the deceased at a rate of 100% and then redistributes the collection evenly to people alive in the next period. A more realistic but technically more challenging setup is to introduce intergenerational transmission within families into the model to account for the differentials in the accumulation of wealth between high- and low-wealth households. This extra heterogeneity is expected to raise the degree of wealth concentration and probably reverse the conclusion of this study, casting the progressive wealth tax reform $\mathcal{P}^2$ in a more favorable light.

There exists room for further improvement with respect to the calibration of the proposed model to match the data. Ideally, we want to have a set of data targets, each of which is sensitive to the change of a particular parameter exclusively. In practice, there seldom exists a clear-cut one-to-one mapping between the parameters to be calibrated and the data targets. In the current model, the transaction costs and the collateral-borrowing function of housing asset play an important role in inducing the early-life saving and late-life dissaving differentials across households. However, none of the data targets is directly related to the housing-preference parameter, θ, except the ratio of total financial assets to total housing stock, which is used to calibrate β instead. Why don't I consider a more suitable data target to replace the current data target for θ, i.e., the total wealth held by business households? It is because I want to retain useful macro statistics that could help the model better characterize the business household's behavior, and in the meantime, I need to keep the size of the parameter space under control in exchange for the computational feasibility in performing the global optimization techniques for calibration. A refined but time-consuming calibration would be to enlarge the parameter space by adding one more dimension to include a parameter that is currently set up by referring to a well-adopted value in the literature. Then let the information of aggregate housing asset be separated from the data target for β so as to be explicitly left for calibrating the value of θ. Besides, I could also take the information about inequality indices into consideration when I calibrate the proposed model to match the U.S. economy. This would be a rewarding extension of the current work but also increases the computational burden in performing model calibration in a much higher dimensional parameter space. I leave this expansion for future research when more powerful computers and advanced algorithms are available.

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Appendix A

Estimation of the partially linear model

The estimation procedure consists of three steps. Let y be the vector of housing asset holdings in the synthetic cohort panel data, be the dependent variable of the partially linear regression analysis, and let X be the design matrix for the cohort and time dummies. First, compute the smoother matrix S of kernel regression such that $\hat{y}_{it} = \hat{m}(age_{it})$ and $\hat{y} = Sy$, where $\hat{y}$ is the vector of the fitted values related to y. Then, to prepare for disentangling the effect of age, compute the partial residual vector $\tilde{r} \equiv (I - S)y$, where I is the identity matrix and the adjusted design matrix is $\tilde{X}$ defined as $(I - S)X$. The second step is to apply the least squares method to estimate the coefficients of the linear part of the partially linear regression model. The estimate of the coefficients of the linear regression model $\tilde{r} = \hat{b}'\tilde{X}$ is given by $\hat{b} = (\tilde{X}'\tilde{X})^{-1}\tilde{X}'\tilde{r}$. The final step is to estimate the function $m(age_{it})$ using the Nadaraya-Watson estimator, taking as the dependent variable $y - X\hat{b}$.

Figure A.1 on page 105 display the financial wealth holding of the median worker households. The trend that looks smoother (colored in red) is the age profile estimated by the partially linear regression model defined in chapter 3. The zigzag line (colored in blue) represents the age profile confounded by cohort and survey-year effects and is formed directly by connecting data points in the SCF pseudo panel data in 1983-2013. It is apparent that the smoothed age profile is S-shaped. The estimated age profile doesn't follow the major trend of the zigzag line. The digression implies that the cohort and survey-year effects dominates the age effect on the life-cycle pattern of household financial wealth holding.

Figure A.2 shows the age profile of the housing equity held by the median worker households. The smoothed age profile reaches a plateau in early 40s. This empirical finding is in line with the observation in Yang (2009), whose pseudo panel data are compiled from the same SCF survey data except that her analysis covers less surveys.

Figure A.3 on page 106 displays the age profile of financial wealth holding of the median business households. The dissaving behavior of business households is hardly observed in the smoothed age profile of financial wealth holding. The negative financial wealth holding observed in the early 40s of the median worker households is missing in the business household's age profile of financial wealth holdings. Instead the latter not only has turned positive in the early stage of lifetime and grows steadily even after the retirement age of 65.

Figure A.4 plots the age profile of housing asset holding of the median business households. The median business households' housing equity holdings grow in a milder pace relative to their financial wealth holdings. However, relative to its counterpart for worker households, the level of the median business households' home equity holding is larger roughly by a factor of 10.

Table A.1: The linear part of partially linear regression results.

$$y_{it} = constant + \sum \beta_i cohort_i + \sum \beta_t year_t + m(age_{it}) + \varepsilon_{it}, \tag{A.1}$$

where y_{it} is the level of a specific statistic of household asset holdings for cohort i in the survey of year t, the variable $cohort_i$ is a dummy for each cohort i except the oldest one, $year_t$ is a dummy for each survey year t , $m(age_{it}) = E(y_{it}|age_{it})$ is a nonlinear smoothing function of age_{it}, where age_{it} denotes the age of cohort i in the survey year t, $\{\beta_j\}$ are parameters for cohort $(j = i)$ and time $(j = t)$ effects, respectively, and ε_{it} is an independent, zero mean, random error.

	Worker households		Business households	
Variable	housing asset	financial wealth	housing asset	financial wealth
Cohort dummy				
1956	12384.09	9496.19	68683.23	68297.50
1951	23418.31	12654.22	42393.54	17670.54
1946	43055.27	32740.74	55160.07	99781.36
1941	36089.87	37484.45	39021.99	96393.74
1936	35304.66	37511.58	23212.00	33351.04
1931	34058.23	47007.68	-11047.32	51557.42
1926	20780.45	57507.69	-51518.11	-302314.43
1921	24239.70	48923.93	17498.11	165224.86
1916	42638.33	73524.67	-111013.94	-234880.87
1911	2095.29	42226.36	-48729.11	-343840.17
Year dummy				
1983	-67723.89	-35952.96	-66804.65	-9283.93
1986	68266.78	36216.04	67478.89	9821.38
1989	10282.00	-1411.06	-1802.13	150381.11
1992	-15525.82	-5703.87	8285.84	-35408.10
1995	-6792.20	-8347.32	-30965.82	-135540.83
1998	666.86	9012.97	2289.62	-196409.82
2001	-2392.32	21965.80	-9276.14	91278.60
2004	31973.87	4137.39	46018.49	125023.23
2007	27359.02	-1357.84	50918.60	51311.76
2010	-14388.91	-7739.75	-11288.59	1741.21
2013	-31725.40	-10819.39	-54854.10	-52914.60

Entries are partially linear regression coefficients.

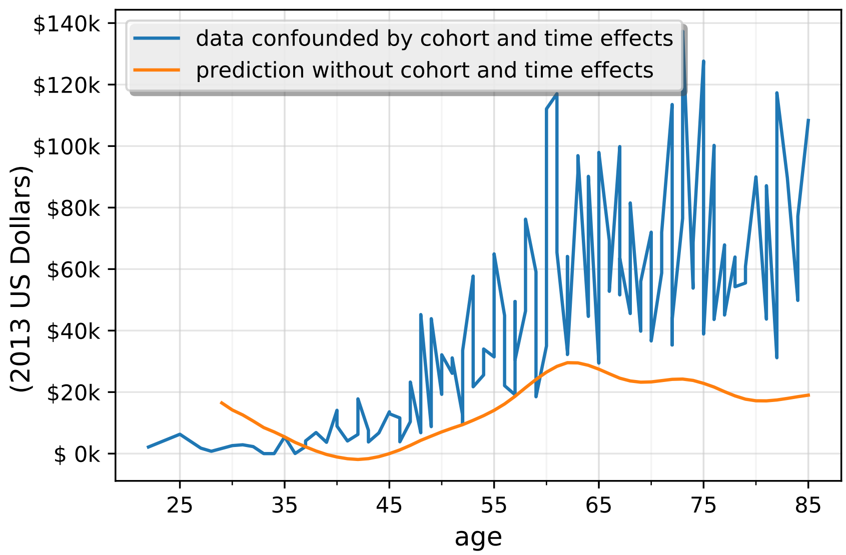

Figure A.1: Median worker household financial assets holding.

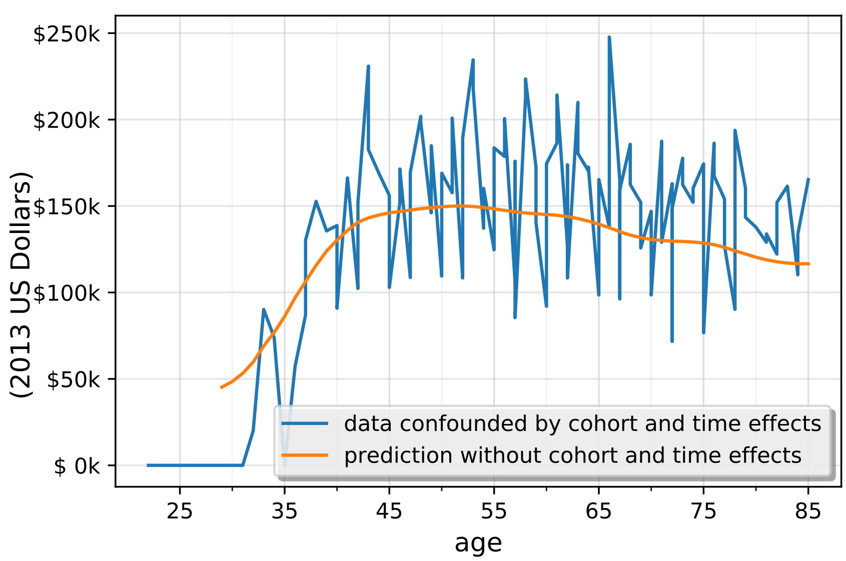

Figure A.2: Median worker household housing asset holding.

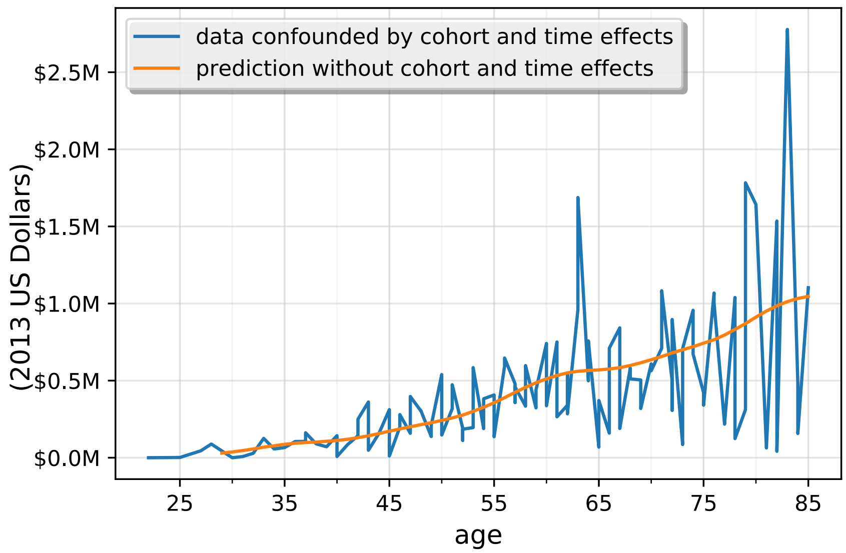

Figure A.3: Median business household financial assets holding.

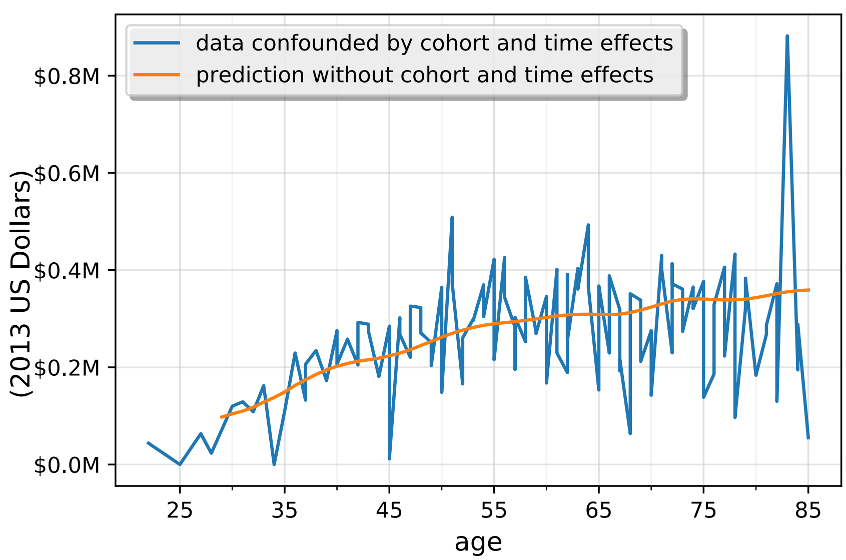

Figure A.4: Median business household housing asset holding.

Appendix B

Computational procedure

I construct a two-dimensional grid for approximating the decisions with respect to the two continuous state variables, housing and non-housing assets, with discrete levels. The maximum asset level is chosen such that, in the stationary equilibrium, the measure of agents with the asset level is zero. The lower bound is chosen as the maximum amount that an agent can ever borrow. The grid is not evenly spaced in the way that the distance between adjacent points are finer at lower levels of assets and coarser at higher levels. The procedure is parsed into the following steps:

1. Given all parameter values, the procedure begins with guessing the equilibrium interest rate r_d (and wage rate w), and the proportional income tax rate, τ_{st}. Taking these as given, solve for the policy functions of housing stock, financial asset holding, and business investment, $\{g_a(\cdot), g_h(\cdot), g_k(\cdot)\}$, across 14 periods of a life cycle.

2. Construct the transition matrix M based on the policy functions $\{g_a(\cdot), g_h(\cdot), g_k(\cdot)\}$ and transition probabilities of $\{k, z, y\}$. Then compute the associated invariant distribution over all the combinations of states and periods of time, starting with a guess for the initial distribution of model entrants $\mu_1^{[1]}$ and compute $\mu_{g+1}^{[1]} = M\mu_g^{[1]}$ for later periods, $g = 1, \ldots, T-1$, where the superscript $[n]$ indicates the variable being loaded/computed in the n-th round of iteration. Update the distribution of new entrants according to bequest distribution and intergenerational transition of labor productivity to get new distribution of model entrants $\mu_1^{[2]}$.

3. Repeat the proceeding step until the difference between $\mu_g^{[n+1]}$ and $\mu_g^{[n]}$ for each g is smaller than a given convergence criterion, i.e., the distribution is invariant.

4. Check to see whether the government budget balances. If it doesn't, update τ_{st} and repeat steps 2–4 until the government budget balance condition is satisfied.

5. Given the obtained invariant distribution $\{\mu_g^{[n+1]}\}_{g=1}^{T}$, compute total wealth in the economy, and total capital invested as well as total labor demanded in the entrepreneurial sector. Compute labor and capital employed in the corporate sector. Check to see if implied interest rate $r_d^{[n+1]}$ is in the neighborhood of $r_d^{[n]}$. If it does, stop the computational procedure. Otherwise, update all the prices and the proportional income tax rate τ_{ss} with the secant method. Repeat steps 1–5 until r_d converges.